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MONTANA AIR POLLUTION STUDY

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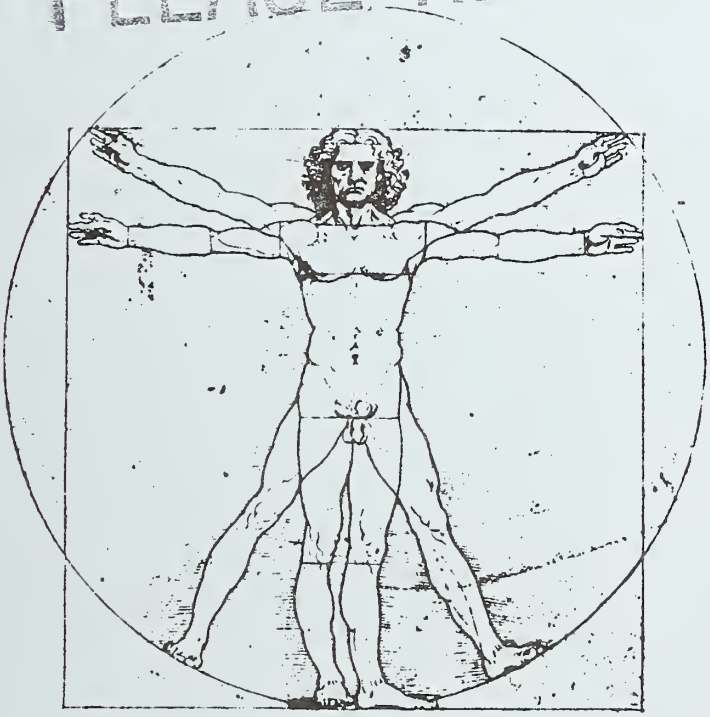

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METEOROLOGICAL SUMMARY - BILLINGS

NOVEMBER, 1980

PREPARED BY

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Consulting Meteorologist
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MONTANA AIR POLLUTION STUDY

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PREFACE

This document is one of a series of technical reports representing results from the Montana Air Pollution Study (MAPS), a special air monitoring and health effects project of the Air Quality Bureau, Montana Department of Health and Environmental Sciences. The MAPS project was initially funded by the 1977 Montana Legislature with $1.07 million for the 1977-79 biennium in order to develop an improved understanding of how air pollution affects human health in Montana. The 1979 Montana Legislature continued the project with $350,000 for 1980-81 biennium in order to complete analyses of the air pollution and health effects data.

The various MAPS activities have been grouped into five major categories for purposes of project management: Health Effects, Air Quality, Meteorology/Modeling, Emission Inventory, and Statistics and Data Systems. Results from each of these technical areas are presented in a series of reports prepared by the personnel directly involved in each MAPS category. A final report to the public also will be prepared.

This specific report, in the Meteorology/Modeling area, presents results of the 1977-80 study of surface and upper air meteorology in the Billings area. The study was designed and coordinated through 1979 by James Gelhaus of the Air Quality Bureau. Hal Robbins and Stan Sternberg coordinated and completed the project in 1980 and 1981. James Gelhaus, presently a senior meteorologist with BISON Engineering/Research, was the principal author of this final report.

I. INTRODUCTION

Meteorological conditions have a major effect on the frequency and severity of pollution concentrations in the air. The ability of the lower atmosphere to disperse, dilute and mix pollutants released into it can vary immensely with meteorological fluctuations from day to day, week to week, and season to season. These meteorological variations are a major influence on air pollution concentrations. Therefore, it is essential that such meteorological variations be measured and compared with the associated changes in pollution to determine their relationship. Only through the analysis of air quality and meteorology together is it possible to describe, anticipate, or predict accurately the ambient pollution concentrations.

The lower atmospheric air movement patterns typical of the mountainous terrain found in the western part of the country are far more erratic than those over flat terrain. Valley-mountain terrain causes air movement patterns that frequently vary greatly over short distances. Several Montana cities are located in valleys surrounded by mountains. In these areas, the escape of pollutants from the valley "bowl" is very limited under certain meteorological conditions, such as low winds and temperature inversions.

The meteorological network established in Montana in the past, primarily by the National Weather Service, has provided a basis for describing or forecasting the general weather conditions that apply to large areas, usually the size of several counties. The major forecast emphasis has been on temperature, precipitation, and the occurrence of storms accompanied by high winds, blizzards, flooding, and other such phenomena. This data network is not adequate to

provide data needed to identify and to understand local meteorological effects on air pollutions.

One of the objectives then of the Montana Air Pollution Study (MAPS) was to define more clearly the primary meteorological parameters that affect air pollution levels in the various study areas. This particular report summarizes data collected during the meteorological study of the Billings area. An initial MAPS report was prepared summarizing the first year of study (Gelhaus, 1979). This report completes the analysis through the end of the study.

In the planning of MAPS, several technical advisory committees were established to review the data needs and make recommendations on the project design. The MAPS Advisory Committee for Meteorology/Modeling reviewed the present data sources in the study areas and compared these sources with the data needs. Priorities were then assigned to determine which meteorological parameters should be measured initially to describe each area more clearly. The MAPS staff, following the recommendations of the advisory committee, implemented a network of meteorological monitors to provide data needed to identify and to understand meteorological effects on air pollution in each study area.

II. STUDY DESIGN AND METHODOLOGY

A. Site Description

The Billings study area primarily included the Yellowstone River Valley in southcentral Montana (Billings-Laurel metropolitan area). The valley, elevation 3100-3600 feet MSL, is situated where the Great Plains meet the Rocky Mountains. The immediate Billings area is prone to air stagnation problems due to the cliffs or rimrocks enclosing much of the metropolitan area. Inversions and slow wind speeds trap air pollutants in the area below the cliffs for extended periods of time.

Since the majority of industrial activity and Billings area population is located below the cliffs, the MAPS project concentrated the meteorological and air quality monitoring in this area. In order to cut costs in conducting the MAPS monitoring program, sites for air quality and meteorological monitoring were combined wherever possible in all cities studied. In the Billings area, one primary surface meteorological station was chosen, the Central Park site in west-central Billings. This site was chosen to describe the surface meteorological conditions in the center of the Billings area. Data on surface meteorological conditions already were being collected at the National Weather Service station in Billings' Logan Field International Airport, located on top of the adjacent cliffs. The MAPS Advisory Committee for Meteorology/Modeling also recommended that one station would be sufficient to describe the area's upper air meteorology. Because of the instrumentation selected, an upper air site had to be chosen to exclude as much residential population and ambient noise as possible.

(The instrumentation included an acoustic radar, which transmits a high-pitched, easily heard sound pulse. The radar is used primarily to measure inversion height, thickness, and breakup.) The site chosen for the upper air measurements was west of Billings at the Vocational, Technical and Career Placement Center (Vo-Tech).

B. Measurement Methods

The meteorological measurements were designed primarily to support health effects, air quality, and modeling studies. The health effects program was concerned with the measurements affecting air pollutant concentrations and human respiratory functions. These studies then were interested in surface measurements (surface indicating measurement near breathing heights of humans or within several meters of the ground) of wind speed, wind direction, temperature, atmospheric pressure, relative humidity (or dewpoint), and stability. (For a discussion of the technical terms used in this report, a glossary is provided at the end of this report). The air quality studies also were concerned with meteorological conditions affecting air pollutant concentrations around sampling stations. The meteorological parameters of concern were wind speed, wind direction, atmospheric pressure, temperature, relative humidity and stability. However, the air quality measurements indirectly were dependent on upper level wind flow (wind flow in the lower 1000 meters of the atmosphere). The modeling, or atmospheric simulation modeling, is not only dependent on the surface wind speed, wind direction, temperature, atmospheric pressure and stability, but also on the upper level wind flow, mixing height, and temperature lapse rates.

Using the requirements of the other MAPS programs as a guide, the basic parameters necessary for the meteorology study were surface wind speed, wind direction, temperature, atmospheric pressure, stability, relative humidity (or dewpoint), solar radiation, and upper level wind speed, wind direction and temperature lapse rate. Standard techniques were employed to measure most of the necessary parameters. This included the measurements of surface wind speed and direction, using a standard cup anemometer and vane mounted on a ten-meter tower at the Central Park site. Temperature measurements were taken using a thermistor mounted on the same tower. Dewpoint measurements also were taken on the tower using an aspirated dew cell. Solar radiation measurements were taken using a broadband pyranometer mounted on top of the instrument shelter. Atmospheric pressure measurements also were made on the ten-meter tower. All measurements taken were reduced to hourly average values with the exception of wind, which also had peak wind gusts recorded. (Table 1 lists the basic parameters measured at all sites in the Billings area.)

The National Climatic Center, Asheville, North Carolina, supplied the study with the surface meteorological observations from the Billings National Weather Service (NWS) station. Information on wind speed, wind direction, temperature, dewpoint temperature, pressure, precipitation, and cloud conditions was included.

The upper level meteorology measurements created special problems in the MAPS project related to analysis procedures and data handling. Measurements of upper level wind flow were made using pilot balloons tracked by a single manually operated theodolite. The balloons were launched at the Vo-Tech site three days a week (Monday, Wednesday, and Friday) at one-half hour after sunrise (most stable atmospheric period of the daylight hours) and at 1400

TABLE 1
BILLINGS AREA METEOROLOGICAL
SITES AND PARAMETERS

SITE	PARAMETERS MONITORED
Central Park	Wind speed (10 meter) Wind direction (10 meter) Solar Radiation Temperature Dew Point Barometric Pressure
Vo-Tech	Stability Vertical Temperature Lapse Rate Upper Level Wind Speed & Direction
National Weather Service (Logan Field)	Wind Speed Wind Direction Temperature Relative Humidity Barometric Pressure Precipitation Cloud Conditions

MST (most unstable atmospheric period). Balloons were tracted taking measurements every thirty seconds for twenty minutes. Balloons were thirty-gram red meteorological balloons filled with helium to pre-determined lift rates shown in Table 2. (The lift rate was determined to provide certain rise rates from field measurements conducted at Bozeman, Montana (Super, 1972).) The balloons also carried aloft temperature thermistors and transmitters (t-sondes). The balloon lift rate was measured after the t-sonde weight was added to the balloon. The t-sondes provided continuous measurements of temperature vertically to a height of about 2000 meters.

A computer system had to be designed and programmed to handle the data and provide a summary usable in the modeling and air quality studies. The computer system was part of a system entitled the Montana Air Resources Modeling System (Gelhaus, 1979 for further discussion). However, mixing heights were reliant on their surface temperature used as a starting point. Procedures used by others have included actual surface temperature or surface temperature plus 2.5, 5.0, or 7.5 degrees Celsius. The temperature addition is designed to account for surface mixing due to the winds flowing over or around trees, buildings, or other obstructions, and the heat island effect of the pavement, home heating, and so forth. However, since Montana cities are not as large as many previously studied cities, a temperature addition as large as 5^{o} or 7.5^{o} seemed to large. MAPS personnel decided to calculate the morning mixing heights through use of the surface temperature plus 2^{o}C., and the afternoon mixing height by using the actual surface temperature plus 2^{o}C. The lapse rates also were categorized by Holzworth Lapse Rate Categories (Table 3) in order to allow discussion of non-inversions and inversions by general strength category.

TABLE 2
Lift Rates for Various Balloons*

Weight No.	Weight (g)	Lift Rate (m/sec)+
1	72.0	2.75
2	33.9	1.78
3	15.0	1.28
4	5.7	0.78

*Rates apply to Weather Measure 30g balloons only

+Reference Super (1972)

TABLE 3
Holzworth Lapse Rate Categories (Modified)
Values in deg C/100m

Non-Inversion Class	Lapse Rate	Description
1	< -1.60	Very Superadiabatic
2	-1.21 to -1.60	Superadiabatic
3	-0.81 to -1.20	Near Dry Adiabatic
4	-0.41 to -0.80	Near Standard Atmosphere
5	0.00 to -0.40	Weak Lapse

Inversion Class	Lapse Rate	Description
1	0.00 to +0.47	Weak Inversion
2	+0.48 to +1.14	Moderate Inversion
3	+1.15 to +2.82	Strong Inversion
4	+2.83 to +6.00	Very Strong Inversion
5	> +6.00	Extreme Inversion

(Holzworth, 1974)

The balloon system provided MAPS with data on upper level wind flow, temperature lapse rates, and mixing heights. A system had to be designed, however, to measure atmospheric stability. Since stability is not a parameter that can be directly measured, such as wind speed or temperature, the system for obtaining stability data had to be selected. Many schemes for determining stability are available. Some rely principally on NWS measurements, and others use sophisticated meteorological measurements such as temperature lapse rate from two to ten meters and standard deviation of the horizontal wind direction. MAPS personnel selected the acoustic sounder or radar coupled with the other surface meteorological instruments as the method to determine stability. The sounder was selected because (1) the sounder produces a continuous record of temperature discontinuities and wind shears up to a height of 1000 meters, (2) the sounder record then could be interpreted by a meteorologist to determine relative atmospheric stability, and (3) the sounder also provided a continuous record of mixing height and temperature inversion information. The acquisition of the sounder was designed to provide (after the MAPS program had ended) a method to continue the measurement of upper level atmospheric conditions without the use of expensive and one-time temperature measurements using t-sondes. The acoustic sounder then was selected to record stability, mixing height, and inversion information. A scheme was designed to reduce the acoustic sounder record to six-hour average inversion heights, thicknesses, and types, and two-hour average relative stability. Account also was made of special meteorological events such as inversion formation or breakup, frontal passage, and precipitation. A computer system was designed to summarize the data and store them on file (Gelhaus, 1979). In the computer system, a method was devised to refine the relative stability determinations made by the

meteorologists to six standard (Pasquill) stability classes (A-F). The refining method relied on wind speed, cloud height and cover from NWS observations, and the sun's elevation angle.

III. DISCUSSION OF RESULTS

As discussed in Section II, a variety of meteorological parameters was measured in the MAPS meteorological study. Some of these parameters were measured to provide support to health effects, air quality, or modeling studies. Discussed alone, these parameters have little or no meaning to the general public. Those parameters of more interest will be discussed in this section. The section is divided into summaries of the surface meteorology and the upper air meteorology. However, in some cases, no distinct separation between upper air and surface air is evident, and parameters falling in this gray area are arbitrarily discussed in one subsection or another.

A. Surface Meteorology

Surface wind data from two sites in the Billings area were available for this report (see Table 1): 1) National Weather Service (Logan Field), located on the rimrocks north of the city, and 2) Billings Central Park in downtown Billings. The data from the Central Park site consist of hourly means of wind speed and direction (in addition to the other parameters listed in Table 1), while the National Weather Service (NWS) data are composed of instantaneous values of wind speed and direction at three-hour intervals. Accordingly, caution should be exercised when comparing the NWS data with those from the other sites.

Data acquisition on surface wind began at Central Park in August 1978. Data through May 1980 were examined for this report, and Table 4 summarizes the surface wind data at the Central Park site. Presented are the monthly average wind speed and direction, prevailing wind direction, percentage of

TABLE 4
Surface Wind Summary
Billings Central Park Site

Month/Year	Average Wind Speed (m/sec)	Average Wind Dir. (degrees)	Prevailing Wind Dir. (degrees)	Percent Calm Winds (percent)	Wind Speed Less Than 1.5 m/sec. (percent)
August 1978	1.0	213	270	11.0	84.8
September	1.6	240	270	8.8	64.6
October	2.1	235	270	0.8	47.3
November	2.6	215	270	0.0	30.6
December	3.4	244	270	0.0	20.0
January 1979	*	*	*	*	*
February	*	*	*	*	*
March	*	*	*	*	*
April	*	*	*	*	*
May	2.3	185	270	1.9	43.3
June	2.3	198	270	0.7	38.2
July	2.3	161	135	0.5	42.2
August	*	*	*	*	*
September	*	*	*	*	*
October	1.1	205	270	11.4	77.5
November	1.5	169	270	5.1	52.8
December	*	*	270	2.4	42.7
January 1980	1.4	179	245-270	23.8	63.2
February	1.0	188	270	43.6	72.2
March	1.3	186	270	31.2	63.1
April	1.7	184	245-270	24.0	56.3
May	1.2	164	*	10.7	68.6

*Insufficient data to compute statistics

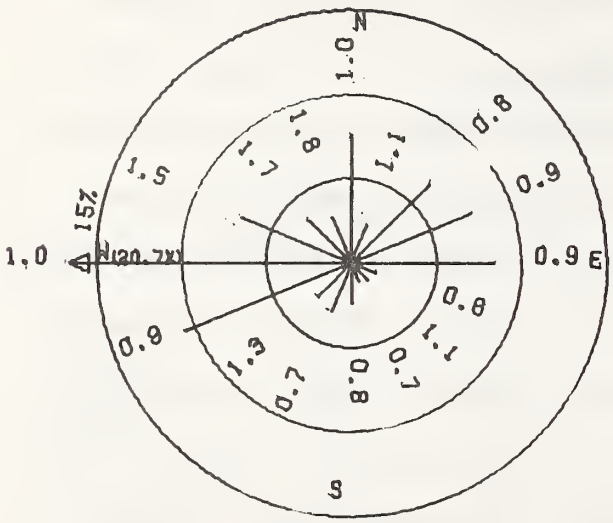
hours having calm wind speeds, and percentage of hours having wind speeds less than 1.5 meters per second (m/sec). The average wind speeds ranged from a low of 1.0 m/sec in August 1978 and February 1980 to a high of 3.4 m/sec in December 1978. Large gaps of missing data during the late winter, spring, and late summer of 1979 prevented a more accurate summary from being presented. In general, though, wind speeds in late 1979 and the first half of 1980 were much slower than wind speeds in previous months. Monthly average wind directions are presented in Table 4 for information only. More appropriate to air quality considerations is the prevailing wind direction. Table 6 lists the monthly values where sufficient data were available for determination. In all months except July 1979 the prevailing wind direction at the Central Park site was westerly. During July 1979 the prevailing wind direction switched to south-easterly. Hours having calm winds (wind speeds less than 0.1 m/sec) occurred frequently at the Central Park site. During the first half of 1980, the calm winds occurred more than 25 percent of the hours. This high occurrence of calm winds is reflected in the very low monthly average wind speeds. The percentage of hours having wind speeds less than 1.5 m/sec also is very high in 1980. These statistics, however, have a high occurrence in all months where data were available. The highest occurrence was in August 1978, when almost 85 percent of the hours fall into this category. The slow wind speeds are very relevant to air quality considerations as higher wind speeds tend to "cleanse" the area of air pollution by diluting and transporting the pollution downwind. With slow wind speeds the air pollutants tend to accumulate or stagnate.

The wind roses (wind frequency diagrams) shown in Figures 1-5 show the monthly distribution of the surface-wind speed and direction for the Central

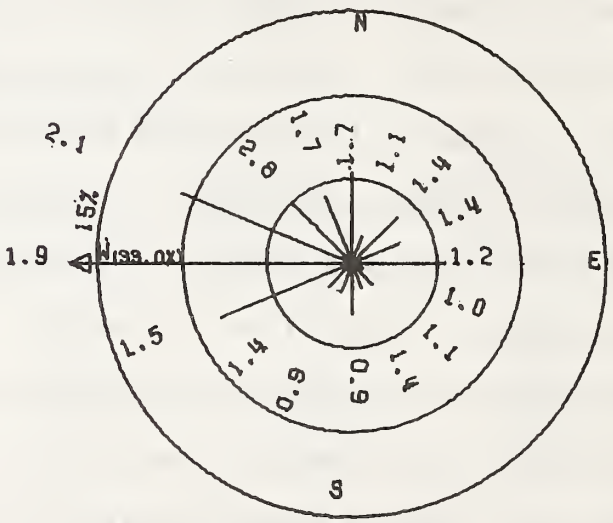
Figure 1

SURFACE WIND ROSES

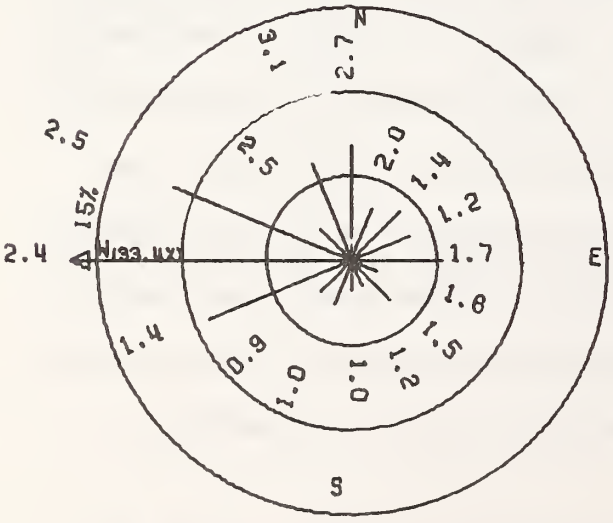
SITE: 80059 MAPS-CENTRAL PARK BILLINGS
BILLINGS MONTANA



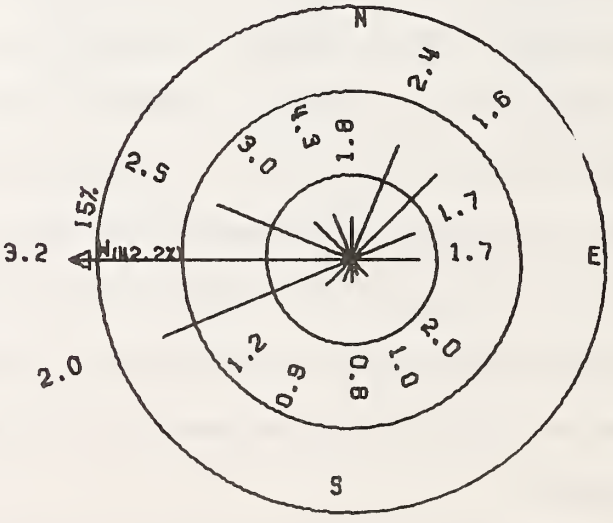
AUGUST 1978
HOURS 0 TO 23
CALM 11.0%
(TOTAL HOURS 459)



SEPTEMBER 1978
HOURS 0 TO 23
CALM 8.8%
(TOTAL HOURS 649)



OCTOBER 1978
HOURS 0 TO 23
CALM 0.8%
(TOTAL HOURS 614)

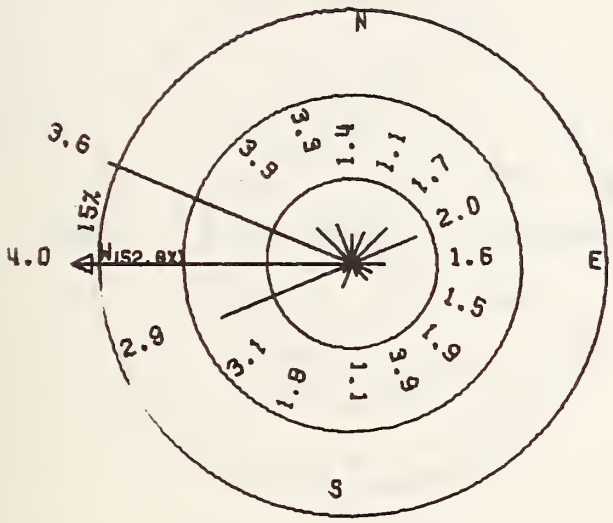


NOVEMBER 1978
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 529)

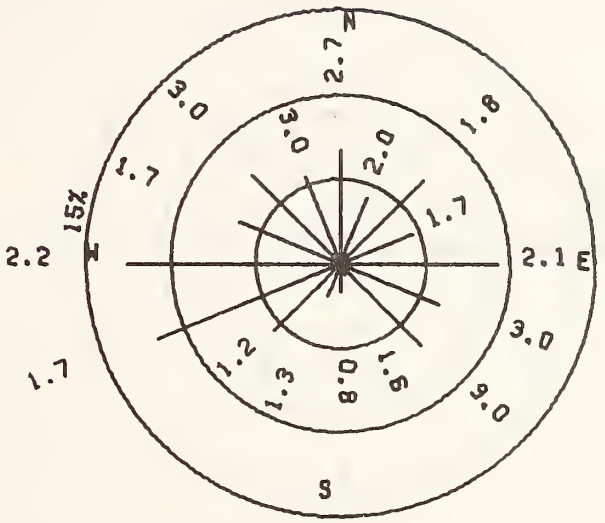
Figure 2

SURFACE WIND ROSES

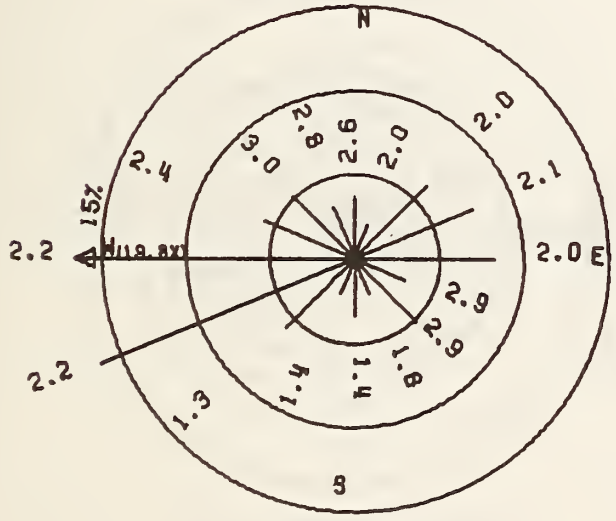
SITE: 80059 MAPS-CENTRAL PARK BILLINGS
BILLINGS MONTANA



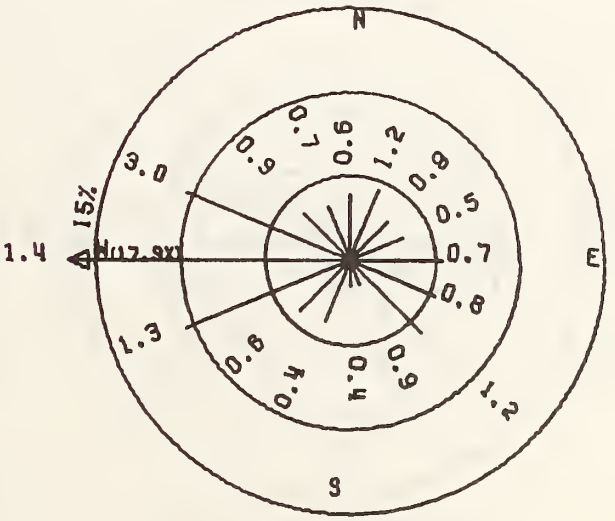
DECEMBER 1978
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 411)



MAY 1979
HOURS 0 TO 23
CALM 1.9%
(TOTAL HOURS 424)



JUNE 1979
HOURS 0 TO 23
CALM 0.7%
(TOTAL HOURS 712)

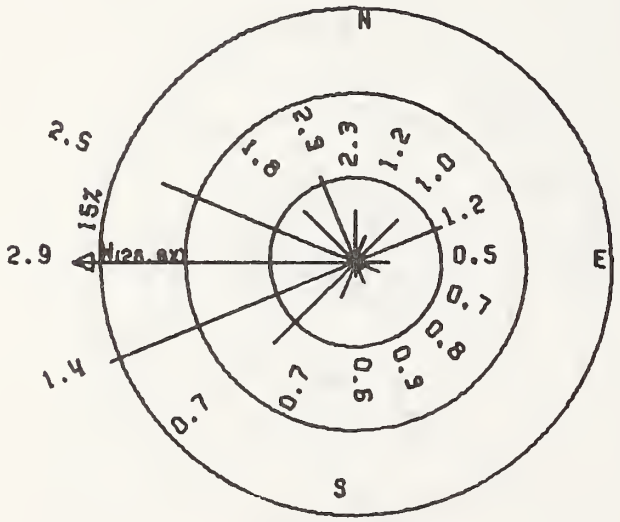


OCTOBER 1979
HOURS 0 TO 23
CALM 11.4%
(TOTAL HOURS 342)

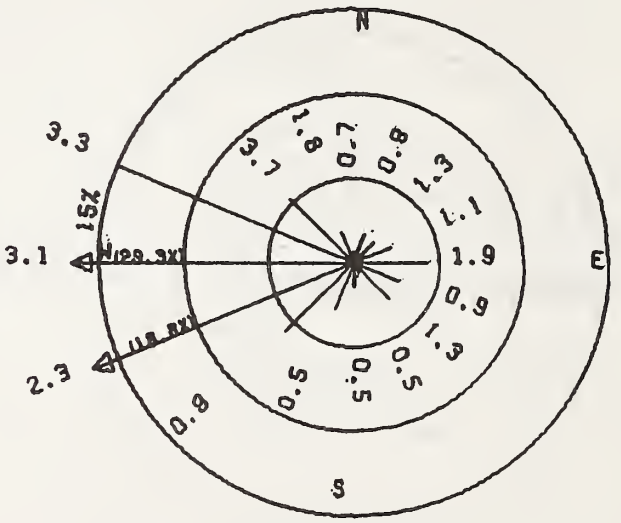
Figure 3

SURFACE WIND ROSES

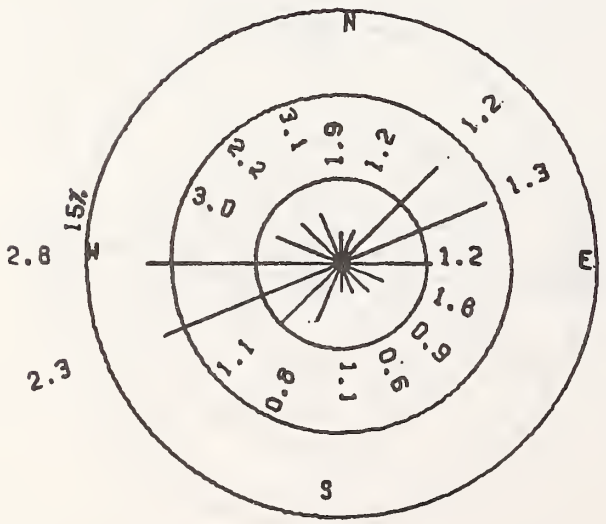
SITE: 80059 MAPS-CENTRAL PARK BILLINGS
BILLINGS MONTANA



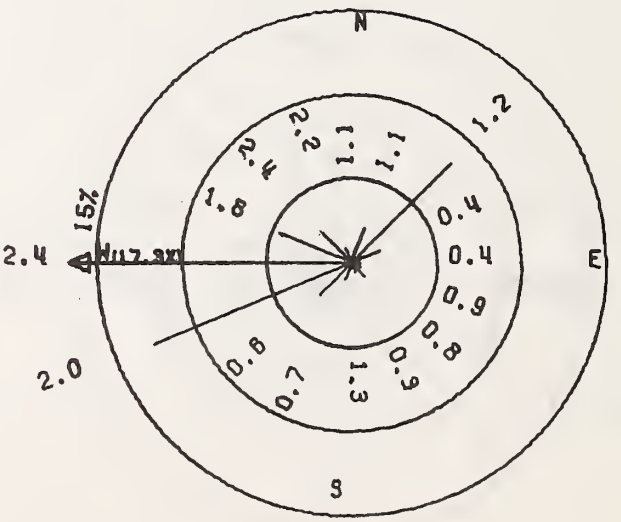
NOVEMBER 1979
HOURS 0 TO 23
CALM 5.1%
(TOTAL HOURS 675)



DECEMBER 1979
HOURS 0 TO 23
CALM 2.4%
(TOTAL HOURS 697)



JANUARY 1980
HOURS 0 TO 23
CALM 23.8%
(TOTAL HOURS 375)

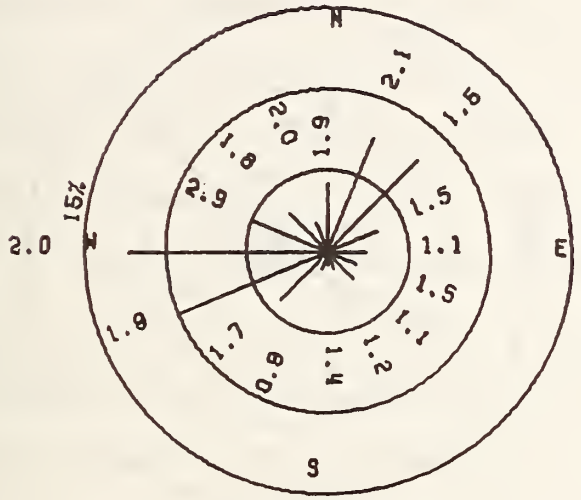


FEBRUARY 1980
HOURS 0 TO 23
CALM 43.6%
(TOTAL HOURS 317)

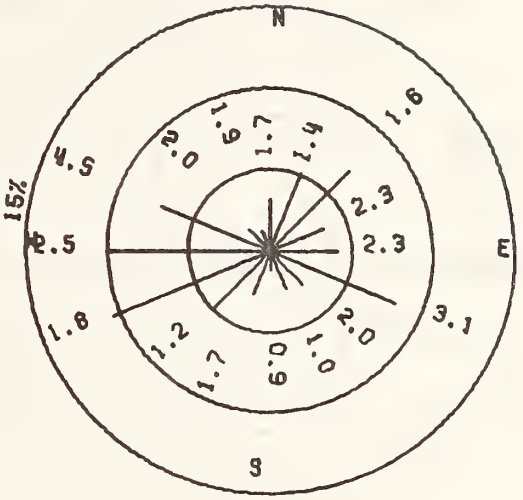
Figure 4

SURFACE WIND ROSES

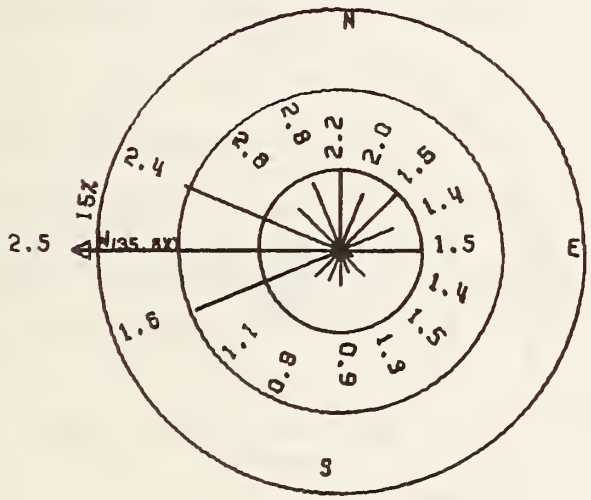
SITE: 80059 MAPS-CENTRAL PARK BILLINGS
BILLINGS MONTANA



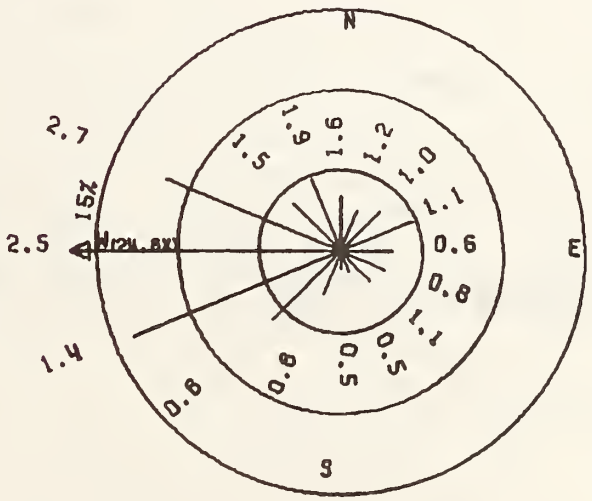
MARCH 1980
HOURS 0 TO 23
CALM 31.2%
(TOTAL HOURS 434)



APRIL 1980
HOURS 0 TO 23
CALM 24.0%
(TOTAL HOURS 403)



9/1/78 TO 11/30/78
HOURS 0 TO 23
CALM 3.7%
(TOTAL HOURS 1792)

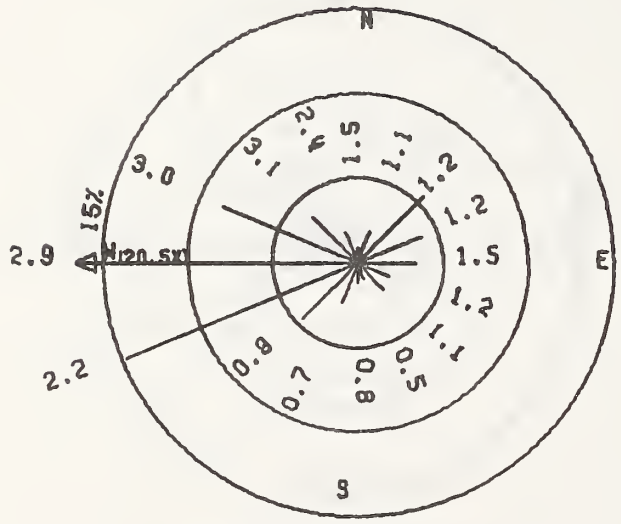


9/1/79 TO 11/30/79
HOURS 0 TO 23
CALM 7.3%
(TOTAL HOURS 1017)

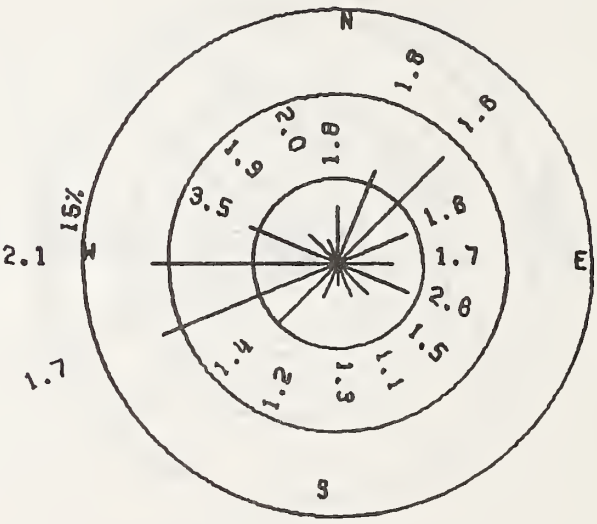
Figure 5

SURFACE WIND ROSES

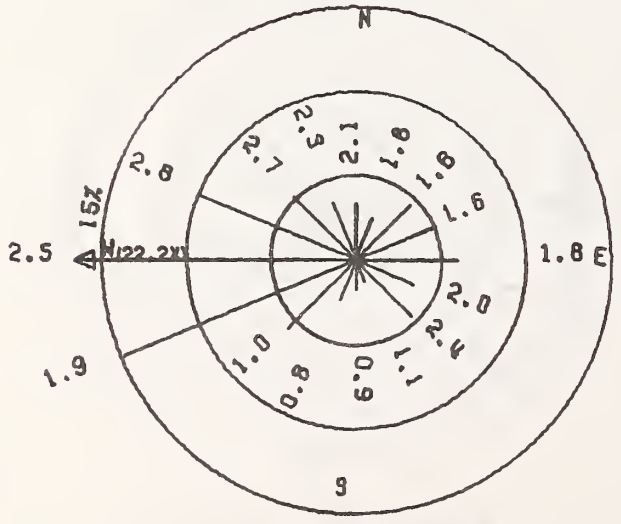
SITE: 80059 MAPS-CENTRAL PARK BILLINGS
BILLINGS MONTANA



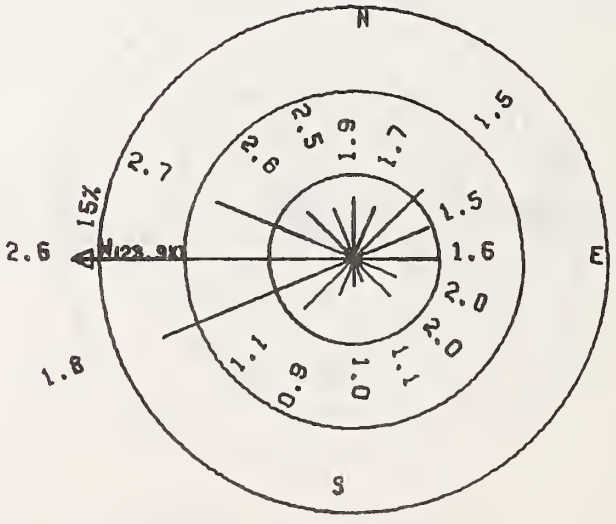
12/1/79 TO 2/29/80
HOURS 0 TO 23
CALM 21.4%
(TOTAL HOURS 1389)



3/1/80 TO 5/31/80
HOURS 0 TO 23
CALM 25.6%
(TOTAL HOURS 996)



1/1/79 TO 12/31/79
HOURS 0 TO 23
CALM 3.5%
(TOTAL HOURS 3060)



6/1/78 TO 6/30/80
HOURS 0 TO 23
CALM 11.3%
(TOTAL HOURS 7410)

Park site. The arrows show the wind's direction and frequency by percentage. At the end of each arrow, the average wind speed in m/sec for that direction for that month is presented. The most common wind direction has an arrowhead attached with the percentage occurrence of that direction. Also presented are statistics on the percentage of calm winds and the total number of hours of data available. No wind rose was plotted for a particular month if less than 50 percent of the data was available.

The wind roses generally show a similar pattern from month to month with the prevailing wind from the west. Secondary maxima occur from the south-southwest through west-northwest and from the east-southeast through northeast. The least common wind directions were from the south through south-southeast. The strongest wind speeds generally were from the west-northwest, while the slowest wind speeds occurred from the south-southwest through south-southeast.

Table 5 summarizes the surface wind data for six hours throughout the day. The table attempts to display the diurnal wind patterns at the Central Park site. (The data are summarized by season and at four-hour intervals throughout the day.) The strongest wind speeds occurred at 1200 or 1600 hours, while the slowest wind speeds occurred at all hours of darkness. This would be expected due not only to the sun's heating of the air, but also to the increased turbulence caused by the heating. Average wind directions show no obvious trend in the diurnal pattern. This lack of pattern also is true for the prevailing wind direction.

B. Upper Air Meteorology

Pilot balloon and temperature sonde soundings were conducted from July 1978 through August 1980 at the Billings Vo-Tech site, located west of Billings. An acoustic radar (sounder) also was utilized for stability and mixing height determinations.

TABLE 5
Diurnal Surface Wind Data
Billings, Montana

Time	Average Wind Speed (m/sec)	Average Wind Direction (degrees)	Prevailing Wind Direction (degrees)
Midnight	1.9	202	270
04	1.9	213	250-270
08(Winter)	1.9	204	270
12	2.3	203	250-270
16	1.9	205	255-270
20	1.6	196	270
Midnight	1.0	185	250-270
04	0.6	191	240-270
08(Spring)	1.6	190	240-255
12	2.4	171	245
16	2.7	164	280
20	1.3	159	270
Midnight	1.1	191	245-270
04	0.9	234	245
08(Summer)	1.6	211	255-270
12	2.2	170	250-270
16	2.6	179	*
20	1.6	170	*
Midnight	1.5	222	270
04	1.5	237	270
08(Autumn)	1.8	230	270
12	2.6	222	270
16	1.9	220	270
20	1.5	224	270

*Insufficient data available

The surface winds at the time of the pilot balloon or pibal launches were generally from the southwest during all months, both morning and afternoon. Average wind speeds at the surface were light. Calm conditions were frequent in the summer but became less frequent during the fall and winter. The winds aloft up to 750 meters were similar in direction to those at the surface, mainly from the southwest or west-southwest. At levels above 750 meters, the wind began to veer with height, becoming westerly at 1000 meters and generally from the west-northwest at 1500 meters. Average wind speeds increased with height, becoming about three times greater at 1500 meters than at the surface. During most months, winds between 200 and 1000 meters were greater in the morning than in the afternoon. Monthly summaries of the 100 and 200 meter winds are presented in Table 6.

Information on inversion base height, thickness, and strength was obtained from temperature sonde traces (see Table 7 for summaries). Inversion and non-inversion strength were categorized according to a modified Holzworth (1974) scheme. Inversions were present for almost all mornings sampled. Most of these inversions were surface inversions, 100-250 meters thick. Very few surface inversions were more than 500 meters thick. In addition to the surface inversion, most mornings also had one or more elevated inversions present. These elevated inversions were most often less than 100 metesr thick. Elevated inversions also were weaker than surface inversions. Generally the elevated inversions were type 1 or 2, whereas the surface inversions were type 2, 3 or 4 (see Table 3).

The afternoons sampled had fewer inversions than the mornings. The afternoons also had a pronounced seasonal variation with least surface inversions occurring during the summer and most occurring during the winter.

Table 6

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - NET.

100 METER LEVEL WINDS MORNING JULY,1978

DIRECTION	******** WIND SPEEDS METERS/SECOND ******** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N		20.0					1	20.0	3.5
NNE							0	0.0	
NE		20.0					1	20.0	3.8
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW	20.0						1	20.0	2.0
SW			20.0				1	20.0	6.0
WSW	20.0						1	20.0	2.5
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	40.0	40.0	20.0				5		3.6

100 METER LEVEL WINDS AFTERNOON JULY,1978

DIRECTION	******** WIND SPEEDS METERS/SECOND ******** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE		25.0					1	25.0	3.9
NE	25.0						1	25.0	2.8
ENE	25.0						1	25.0	2.2
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE	25.0						1	25.0	2.4
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	75.0	25.0					4		2.9

Table 7-1

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING JULY,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N		20.0					1	20.0	4.9
NNE							0	0.0	
NE		20.0					1	20.0	3.3
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	20.0						1	20.0	2.1
WSW							0	0.0	
W							0	0.0	
WNW	40.0						2	40.0	1.4
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	60.0	40.0					5		2.6

200 METER LEVEL WINDS AFTERNOON JULY,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE			25.0				1	25.0	7.7
NE							0	0.0	
ENE	25.0	25.0					2	50.0	4.2
E							0	0.0	
ESE							0	0.0	
SE	25.0						1	25.0	1.7
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	50.0	25.0	25.0				4		4.4

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING AUGUST,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE	9.0						1	9.0	1.3
NE							0	0.0	
ENE							0	0.0	
E		9.0					1	9.0	3.9
ESE							0	0.0	
SE							0	0.0	
SSE	9.0						1	9.0	.3
S							0	0.0	
SSW	9.0						1	9.0	1.2
SW			9.0				1	9.0	6.3
WSW		9.0	9.0				2	18.0	5.5
W	9.0	18.1					3	27.1	2.8
WNW	9.0						1	9.0	.9
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	45.0	36.1	18.0				11		3.0

100 METER LEVEL WINDS AFTERNOON AUGUST,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N		8.3					1	8.3	3.1
NNE							0	0.0	
NE			8.3				1	8.3	6.2
ENE	8.3						1	8.3	2.6
E							0	0.0	
ESE				8.3			1	8.3	13.9
SE							0	0.0	
SSE	8.3	8.3					2	16.6	2.7
S							0	0.0	
SSW							0	0.0	
SW					8.3		1	8.3	20.0
WSW	8.3						1	8.3	2.7
W	8.3						1	8.3	1.3
WNW			8.3				1	8.3	9.3
NW			8.3				1	8.3	9.6
NNW	8.3						1	8.3	.9
CALM							0	0.0	
COL. TOTALS	41.5	16.6	24.9	8.3	8.3		12		6.2

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING AUGUST,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N	9.0						1	9.0	2.3
NNE		9.0					1	9.0	3.6
NE							0	0.0	
ENE							0	0.0	
E		9.0					1	9.0	3.9
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW	18.1						2	18.1	1.7
SW			9.0				1	9.0	6.4
WSW		18.1	9.0	9.0			4	36.1	7.5
W							0	0.0	
WNW		9.0					1	9.0	5.7
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	27.1	45.1	18.0	9.0			11		5.0

200 METER LEVEL WINDS AFTERNOON AUGUST,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N	8.3						1	8.3	1.0
NNE							0	0.0	
NE		8.3	8.3				2	16.6	6.0
ENE							0	0.0	
E							0	0.0	
ESE				8.3			1	8.3	10.6
SE							0	0.0	
SSE		8.3					1	8.3	4.4
S							0	0.0	
SSW	8.3			8.3			2	16.6	5.7
SW		8.3					1	8.3	3.0
WSW		8.3					1	8.3	3.5
W	8.3						1	8.3	2.8
WNW							0	0.0	
NW							0	0.0	
NNW		8.3		8.3			2	16.6	7.3
CALM							0	0.0	
COL. TOTALS	24.9	41.5	8.3	24.9			12		5.2

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING SEPTEMBER,1978

DIRECTION	********* WIND SPEEDS METERS/SECOND *********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW	50.0	50.0					2	100.0	2.4
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	50.0	50.0					2		2.4

100 METER LEVEL WINDS AFTERNOON SEPTEMBER,1978

DIRECTION	********* WIND SPEEDS METERS/SECOND *********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	16.6		33.3				3	49.9	5.4
WSW							0	0.0	
W	16.6						1	16.6	1.5
WNW			16.6				1	16.6	8.4
NW							0	0.0	
NNW	16.6						1	16.6	2.5
CALM							0	0.0	
COL. TOTALS	49.8		49.9				6		4.7

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING SEPTEMBER,1978

DIRECTION	********* WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW		50.0	50.0				2	100.0	6.1
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS		50.0	50.0				2		6.1

200 METER LEVEL WINDS AFTERNOON SEPTEMBER,1978

DIRECTION	********* WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	16.6	16.6					2	33.2	3.3
WSW			16.6				1	16.6	9.2
W		16.6					1	16.6	4.4
WNW			16.6				1	16.6	9.2
NW							0	0.0	
NNW	16.6						1	16.6	2.7
CALM							0	0.0	
COL. TOTALS	33.2	33.2	33.2				6		5.3

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING OCTOBER,1978

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE	9.0						1	9.0	2.5
S							0	0.0	
SSW	9.0						1	9.0	1.6
SW	9.0		9.0				2	18.0	5.0
WSW	9.0	18.1	9.0	9.0			5	45.1	7.1
W							0	0.0	
WNW		9.0					1	9.0	4.5
NW			9.0				1	9.0	7.9
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	36.0	27.1	27.0	9.0			11		5.6

100 METER LEVEL WINDS AFTERNOON OCTOBER,1978

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N		10.0	10.0				2	20.0	5.9
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E	10.0	10.0					2	20.0	2.4
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW					10.0		1	10.0	18.2
SW		10.0	20.0				3	30.0	9.6
WSW		10.0					1	10.0	5.1
W							0	0.0	
WNW			10.0				1	10.0	8.6
NW							0	0.0	
NNW									
CALM							0	0.0	
COL. TOTALS	10.0	40.0	40.0		10.0		10		6.6

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: ILLINOIS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING OCTOBER,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE	9.0						1	9.0	1.6
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE	9.0						1	9.0	1.2
S							0	0.0	
SSW					9.0		1	9.0	20.5
SW			18.1	27.2			5	45.3	10.7
WSW							0	0.0	
W		9.0					1	9.0	4.9
WNW			9.0	9.0			2	18.0	10.4
NW							0	0.0	
NNW									
CALM							0	0.0	
COL. TOTALS	18.0	9.0	27.1	36.2	9.0		11		9.3

200 METER LEVEL WINDS AFTERNOON OCTOBER,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE				10.0			1	10.0	11.2
NE							0	0.0	
ENE		10.0					1	10.0	4.0
E	10.0						1	10.0	1.6
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	10.0				10.0		2	20.0	9.8
WSW			10.0				1	10.0	6.3
W		10.0	10.0				2	20.0	8.2
WNW							0	0.0	
NW			10.0				1	10.0	8.8
NNW		10.0					1	10.0	5.4
CALM							0	0.0	
COL. TOTALS	20.0	30.0	30.0	10.0	10.0		10		6.9

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING NOVEMBER,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE	20.0						1	20.0	1.7
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	20.0		40.0				3	60.0	6.5
WSW		20.0					1	20.0	4.8
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	40.0	20.0	40.0				5		5.2

100 METER LEVEL WINDS AFTERNOON NOVEMBER,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW				33.3			1	33.3	10.1
WSW							0	0.0	
W							0	0.0	
WNW	33.3			33.3			2	66.6	5.5
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	33.3			66.6			3		7.0

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING NOVEMBER,1978

DIRECTION	********* WIND SPEEDS METERS/SECOND *********						ROW SUMMARY		
	00.1 TO 03.9	04.0 TO 08.9	09.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N						0	0.0	
NNE						0	0.0	
NE	20.0					1	20.0	1.7
ENE						0	0.0	
E						0	0.0	
ESE						0	0.0	
SE						0	0.0	
SSE						0	0.0	
S						0	0.0	
SSW			20.0			1	20.0	8.7
SW		20.0				1	20.0	4.8
WSW				40.0		2	40.0	12.2
W						0	0.0	
WNW						0	0.0	
NW						0	0.0	
NNW						0	0.0	
CALM						0	0.0	
COL. TOTALS	20.0	20.0	20.0	40.0		5		7.9

200 METER LEVEL WINDS AFTERNOON NOVEMBER,1978

DIRECTION	********* WIND SPEEDS METERS/SECOND *********						ROW SUMMARY		
	00.1 TO 03.9	04.0 TO 08.9	09.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N						0	0.0	
NNE	33.3					1	33.3	.8
NE						0	0.0	
ENE						0	0.0	
E						0	0.0	
ESE						0	0.0	
SE						0	0.0	
SSE						0	0.0	
S						0	0.0	
SSW						0	0.0	
SW			33.3			1	33.3	7.3
WSW						0	0.0	
W				33.3		1	33.3	14.0
WNW						0	0.0	
NW						0	0.0	
NNW						0	0.0	
CALM						0	0.0	
COL. TOTALS	33.3		33.3	33.3		3		7.3

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - NAPS - MET.

100 METER LEVEL WINDS MORNING DECEMBER,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW		14.2			14.2		2	28.4	10.7
SW		14.2			14.2		2	28.4	11.4
WSW				14.2			1	14.2	10.5
W	14.2						1	14.2	2.4
WNW	14.2						1	14.2	1.3
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	28.4	28.4		14.2	28.4		7		8.3

100 METER LEVEL WINDS AFTERNOON DECEMBER,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE			25.0				1	25.0	6.4
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S	25.0						1	25.0	1.7
SSW			25.0				1	25.0	8.8
SW			25.0				1	25.0	9.1
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	25.0		75.0				4		6.5

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING DECEMBER,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N	14.2						1	14.2	2.2
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW			14.2		28.5		3	42.7	15.7
WSW				14.2			1	14.2	10.7
W				14.2			1	14.2	10.5
WNW							0	0.0	
NW	14.2						1	14.2	1.9
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	28.4		14.2	28.4	28.5		7		10.3

200 METER LEVEL WINDS AFTERNOON DECEMBER,1978

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE			25.0				1	25.0	7.1
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW				25.0			1	25.0	10.0
WSW				25.0			1	25.0	10.2
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW		25.0					1	25.0	3.3
CALM							0	0.0	
COL. TOTALS		25.0	25.0	50.0			4		7.6

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: ILLINOIS - VOTECH - MAPS - MET.

LOW METER LEVEL WINDS MORNING JANUARY, 1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	03.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.2	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE							0	0.0	
ENE		14.2					1	14.2	3.1
E							0	0.0	
ESE							0	0.0	
SSE	14.2						1	14.2	.4
SSW							0	0.0	
WSW	14.2	14.2	14.2	14.2			4	56.8	6.3
WNW							0	0.0	
NNW			14.2				1	14.2	7.4
CALM							0	0.0	
COL. TOTALS	28.4	28.4	28.4	14.2			7		5.1

100 METER LEVEL WINDS AFTERNOON JANUARY, 1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	03.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE	9.0						1	9.0	1.2
ENE		9.0					1	9.0	3.2
E	9.0						1	9.0	.4
ESE							0	0.0	
SSE	9.0						1	9.0	2.7
SSW							0	0.0	
WSW	9.0	9.0	18.1	9.0			4	45.3	6.6
WNW	9.0						1	9.0	2.4
NW			9.0				1	9.0	6.5
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	45.0	18.0	27.1	9.0			11		4.5

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: ILLINOIS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING JANUARY,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE							0	0.0	
NE		14.2					1	14.2	3.2
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S		14.2	14.2				2	28.4	6.7
SSW			14.2	28.5			3	42.7	9.4
SW							0	0.0	
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW			14.2				1	14.2	7.4
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS		28.4	42.6	28.5			7		7.4

200 METER LEVEL WINDS AFTERNOON JANUARY,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE							0	0.0	
NE	9.0						1	9.0	2.7
ENE	9.0						1	9.0	2.3
E	9.0						1	9.0	2.6
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S	9.0	9.0	18.1	9.0			4	36.2	5.5
SSW	9.0		9.0				1	9.0	4.5
SW			9.0				1	9.0	6.5
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	45.0	9.0	36.1	9.0			11		5.0

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - MOTLOW - MAPS - MET.

100 METER LEVEL WINDS MORNING FEBRUARY, 1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE							0	0.0	
NE	16.6						1	16.6	2.5
ENE	33.3						2	33.3	.6
E	16.6						1	16.6	1.7
ESE	16.6		16.6				2	33.3	4.6
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	16.6		16.6				6		2.5

100 METER LEVEL WINDS AFTERNOON FEBRUARY, 1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE							0	0.0	
NE		14.2					1	14.2	3.0
ENE							0	0.0	
E	14.2						1	14.2	1.6
ESE			14.2				1	14.2	6.4
SE	14.2						1	14.2	2.6
SSE							0	0.0	
S	14.2	14.2					2	28.5	3.2
SSW			14.2				1	14.2	7.5
SW							0	0.0	
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	42.6	28.4	28.4				7		4.3

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - NAPS - MET.

200 METER LEVEL WINDS MORNING FEBRUARY,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE		16.6					1	16.6	3.0
NE							0	0.0	
ENE	16.6						1	16.6	2.1
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW		16.6	33.3				3	49.9	5.7
WSW					16.6		1	16.6	18.8
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	16.6	33.2	33.3		16.6		6		6.8

200 METER LEVEL WINDS AFTERNOON FEBRUARY,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N	14.2						1	14.2	1.7
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E		14.2					1	14.2	4.3
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW				14.2			1	14.2	11.1
SW		14.2					1	14.2	5.6
WSW							0	0.0	
W	14.2		14.2				2	28.4	4.7
WNW			14.2				1	14.2	7.5
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	28.4	28.4	28.4	14.2			7		5.6

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: SILLAMOO - JUTECH - MARS - ref.

100 METER LEVEL WINDS MORNING MARCH, 1979

DIRECTION	WIND SPEEDS METERS/SECOND						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.0	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE							0	0.0	
NE		20.0					2	40.0	4.6
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE			40.0				2	40.0	6.8
SSE							0	0.0	
S		20.0	20.0				4	80.0	5.1
SSW							0	0.0	
SW							0	0.0	
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS		40.0	60.0				5		5.6

100 METER LEVEL WINDS AFTERNOON MARCH, 1979

DIRECTION	WIND SPEEDS METERS/SECOND						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.0	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE							0	0.0	
NE		12.5					1	12.5	3.2
ENE	25.0						1	25.0	
E				12.5			1	12.5	10.7
ESE							0	0.0	
SE	12.5		12.5				2	25.0	4.8
SSE				12.5			1	12.5	10.1
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW		12.5					1	12.5	3.4
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	37.5	25.0	12.5	25.0			8		5.4

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: ILLINOIS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING MARCH,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						RCN SUMMARY		
	00.1 TO 02.5	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE							0	0.0	
NE		20.0					1	20.0	3.8
ENE							0	0.0	
E							0	0.0	
ESE		20.0	20.0				2	40.0	7.2
SE			20.0				1	20.0	8.4
SSE							0	0.0	
S			20.0				1	20.0	8.3
SSW							0	0.0	
SW							0	0.0	
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS		40.0	60.0				5		6.9

200 METER LEVEL WINDS AFTERNOON MARCH,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						RCN SUMMARY		
	00.1 TO 02.5	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
NNE							0	0.0	
NE	12.5	12.5					2	25.0	2.9
ENE		12.5					1	12.5	4.3
E				12.5			1	12.5	10.0
ESE	12.5						1	12.5	1.9
SE			12.5				1	12.5	7.9
SSE			12.5				1	12.5	7.5
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW							0	0.0	
W							0	0.0	
WNW							0	0.0	
NW		12.5					1	12.5	5.4
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	25.0	37.5	25.0	12.5			8		5.1

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING AUGUST, 1979

DIRECTION	********* WIND SPEEDS METERS/SECOND *********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE		10.0					1	10.0	3.2
ENE	10.0						1	10.0	1.6
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW		20.0					2	20.0	4.1
WSW	10.0	10.0	10.0				3	30.0	4.8
W	10.0	10.0					2	20.0	2.6
WNW			10.0				1	10.0	8.2
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	30.0	50.0	20.0				10		4.1

100 METER LEVEL WINDS AFTERNOON AUGUST, 1979

DIRECTION	********* WIND SPEEDS METERS/SECOND *********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E		40.0					2	40.0	4.2
ESE							0	0.0	
SE							0	0.0	
SSE	20.0						1	20.0	2.9
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW							0	0.0	
W		20.0					1	20.0	3.7
WNW			20.0				1	20.0	7.9
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	20.0	60.0	20.0				5		4.6

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING AUGUST, 1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW SUMMARY TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE	10.0						1	10.0	2.5
E		10.0					1	10.0	3.1
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW			10.0				1	10.0	9.8
WSW	10.0	30.0					4	40.0	3.3
W	10.0						1	10.0	2.3
WNW		10.0	10.0				2	20.0	6.0
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	30.0	50.0	20.0				10		4.3

200 METER LEVEL WINDS AFTERNOON AUGUST, 1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW SUMMARY TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE			20.0				1	20.0	6.4
E							0	0.0	
ESE	20.0						1	20.0	2.5
SE							0	0.0	
SSE			20.0				1	20.0	7.0
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW							0	0.0	
W		20.0	20.0				2	40.0	6.4
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	20.0	20.0	60.0				5		5.7

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING SEPTEMBER, 1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW	22.2	22.2	11.1				5	55.5	4.1
SW			11.1				1	11.1	7.1
WSW			11.1				1	11.1	9.9
W	11.1						1	11.1	.9
WNW							0	0.0	
NW	11.1						1	11.1	2.3
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	44.4	22.2	33.3				9		4.6

100 METER LEVEL WINDS AFTERNOON SEPTEMBER, 1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N		10.0					1	10.0	5.6
NNE	10.0						1	10.0	.8
NE							0	0.0	
ENE	10.0						1	10.0	2.9
E		10.0					1	10.0	3.2
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S	10.0						1	10.0	1.4
SSW	10.0						1	10.0	1.5
SW		20.0	10.0				3	30.0	4.8
WSW							0	0.0	
W				10.0			1	10.0	11.7
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	40.0	40.0	10.0	10.0			10		4.1

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING SEPTEMBER, 1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW		22.2	33.3				5	55.5	6.3
W				11.1			1	11.1	13.1
WNW							0	0.0	
NW	11.1						1	11.1	2.1
NNW	11.1	11.1					2	22.2	3.6
CALM							0	0.0	
COL. TOTALS	22.2	33.3	33.3	11.1			9		6.0

200 METER LEVEL WINDS AFTERNOON SEPTEMBER, 1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE		10.0					1	10.0	3.2
ENE			10.0				1	10.0	6.8
E							0	0.0	
ESE	20.0						2	20.0	1.0
SE							0	0.0	
SSE	10.0						1	10.0	1.8
S	10.0						1	10.0	1.0
SSW		10.0					1	10.0	4.3
SW		10.0					1	10.0	4.4
WSW			10.0				1	10.0	6.1
W					10.0		1	10.0	16.2
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	40.0	30.0	20.0		10.0		10		4.5

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING OCTOBER,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE	10.0						1	10.0	2.7
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S	10.0						1	10.0	1.2
SSW							0	0.0	
SW		40.0					4	40.0	3.4
WSW	20.0	10.0		10.0			4	40.0	4.8
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	40.0	50.0		10.0			10		3.6

100 METER LEVEL WINDS AFTERNOON OCTOBER,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE	9.0						1	9.0	1.5
NE			9.0				1	9.0	6.7
ENE							0	0.0	
E	9.0						1	9.0	1.2
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S	9.0						1	9.0	.6
SSW							0	0.0	
SW			9.0	18.1			3	27.1	9.9
WSW			9.0				1	9.0	6.7
W							0	0.0	
WNW			9.0				1	9.0	9.4
NW	9.0	9.0					2	18.0	2.9
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	36.0	9.0	36.0	18.1			11		5.6

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING OCTOBER,1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE		10.0					1	10.0	3.3
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE	10.0						1	10.0	1.1
SE				10.0			1	10.0	13.6
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW	20.0	10.0	10.0		10.0		5	50.0	6.8
W		10.0					1	10.0	4.7
WNW							0	0.0	
NW		10.0					1	10.0	3.4
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	30.0	40.0	10.0	10.0	10.0		10		6.0

200 METER LEVEL WINDS AFTERNOON OCTOBER,1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE			9.0				1	9.0	8.3
E	18.1						2	18.1	1.8
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW			18.1				2	18.1	8.3
SW	18.1	9.0					3	27.1	2.0
WSW							0	0.0	
W		9.0					1	9.0	4.6
WNW		9.0					1	9.0	3.0
NW	9.0						1	9.0	1.5
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	45.2	27.0	27.1				11		4.0

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING NOVEMBER,1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	33.3	16.6					3	49.9	3.0
WSW			16.6	16.6			2	33.2	5.9
W	16.6						1	16.6	2.9
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	49.9	16.6	16.6	16.6			6		5.3

100 METER LEVEL WINDS AFTERNOON NOVEMBER,1979

DIRECTION	********* WIND SPEEDS METERS/SECOND ********** 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE	14.2						1	14.2	1.0
NE							0	0.0	
ENE	14.2						1	14.2	2.5
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW		14.2		14.2			2	28.4	3.9
WSW		14.2					1	14.2	3.8
W							0	0.0	
WNW			28.5				2	28.5	7.5
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	28.4	28.4	28.5	14.2			7		5.7

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING NOVEMBER,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW							0	0.0	
WSW		33.3	33.3	16.6			3	83.2	7.2
W			16.6				1	16.6	6.5
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS		33.3	49.9	16.6			6		7.1

200 METER LEVEL WINDS AFTERNOON NOVEMBER,1979

DIRECTION	********** WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE	14.2						1	14.2	1.9
NE							0	0.0	
ENE							0	0.0	
E	14.2						1	14.2	2.7
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW			14.2		14.2		2	28.4	13.3
WSW							0	0.0	
W		14.2					1	14.2	3.8
WNW			14.2	14.2			2	28.4	9.9
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	28.4	14.2	28.4	14.2	14.2		7		7.8

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - WUNDER - MAPS - MET.

100 METER LEVEL WINDS MORNING DECEMBER,1979

DIRECTION	********* WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE		11.1					1	11.1	3.0
ENE		11.1					1	11.1	3.0
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	11.1		22.2				3	33.3	6.3
WSW		11.1	22.2	11.1			4	44.4	8.9
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	11.1	33.3	44.4	11.1			9		6.9

100 METER LEVEL WINDS AFTERNOON DECEMBER,1979

DIRECTION	********* WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE		16.6					1	16.6	3.7
SSE							0	0.0	
S	16.6						1	16.6	.1
SSW				16.6			1	16.6	13.3
SW							0	0.0	
WSW		16.6	16.6				2	33.2	6.1
W				16.6			1	16.6	10.0
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	16.6	33.2	16.6	33.2			6		6.5

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING DECEMBER.1979

DIRECTION	********* WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE			11.1				1	11.1	6.6
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW			11.1	11.1	22.2		4	44.4	13.6
WSW			11.1	22.2			3	33.3	10.1
W							0	0.0	
WNW							0	0.0	
NW	11.1						1	11.1	1.2
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	11.1		33.3	33.3	22.2		9		10.2

200 METER LEVEL WINDS AFTERNOON DECEMBER.1979

DIRECTION	********* WIND SPEEDS METERS/SECOND **********						ROW SUMMARY		
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	TOTAL COUNT	TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE	16.6						1	16.6	2.9
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW						16.6	1	16.6	35.6
SW			16.6				1	16.6	9.7
WSW							0	0.0	
W			33.3				2	33.3	7.4
WNW							0	0.0	
NW							0	0.0	
NNW					16.6		1	16.6	17.9
CALM							0	0.0	
COL. TOTALS	16.6		49.9		16.6	16.6	6		13.1

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING JANUARY, 1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S	20.0						1	20.0	1.8
SSW	40.0						2	40.0	2.2
SW		20.0					1	20.0	5.9
WSW	20.0						1	20.0	2.3
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	80.0	20.0					5		2.8

100 METER LEVEL WINDS AFTERNOON JANUARY, 1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE	12.5	12.5					2	25.0	3.9
E	25.0						2	25.0	1.8
ESE	12.5						1	12.5	1.7
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW		12.5	12.5				2	25.0	5.6
WSW	12.5						1	12.5	1.0
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	62.5	25.0	12.5				8		3.1

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING JANUARY,1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE	20.0						1	20.0	1.5
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW			20.0				1	20.0	9.5
WSW		60.0					3	60.0	4.4
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	20.0	60.0	20.0				5		4.8

200 METER LEVEL WINDS AFTERNOON JANUARY,1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE	12.5	12.5					2	25.0	4.0
E							0	0.0	
ESE							0	0.0	
SE	12.5						1	12.5	2.0
SSE							0	0.0	
S							0	0.0	
SSW	12.5						1	12.5	2.2
SW		12.5	12.5				2	25.0	6.7
WSW	12.5		12.5				2	25.0	5.6
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	50.0	25.0	25.0				8		4.6

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING FEBRUARY,1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE							0	0.0	
E							0	0.0	
ESE	16.6						1	16.6	2.0
SE							0	0.0	
SSE							0	0.0	
S	16.6						1	16.6	1.4
SSW							0	0.0	
SW			16.6				1	16.6	7.3
WSW				16.6		16.6	2	33.2	51.1
W							0	0.0	
WNW							0	0.0	
NW	16.6						1	16.6	.7
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	49.8		16.6	16.6		16.6	6		18.9

100 METER LEVEL WINDS AFTERNOON FEBRUARY,1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE			16.6				1	16.6	8.3
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	16.6	16.6	16.6				3	49.8	4.8
WSW			16.6				1	16.6	8.2
W							0	0.0	
WNW							0	0.0	
NW			16.6				1	16.6	7.3
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	16.6	16.6	66.4				6		6.3

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING FEBRUARY,1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE							0	0.0	
ENE						16.6	1	16.6	153.4
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE	16.6						1	16.6	1.1
S							0	0.0	
SSW							0	0.0	
SW				16.6			1	16.6	12.5
WSW	16.6	16.6		16.6			3	49.8	5.8
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	33.2	16.6		33.2		16.6	6		30.7

200 METER LEVEL WINDS AFTERNOON FEBRUARY,1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE			16.6				1	16.6	6.3
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	16.6		16.6				2	33.2	5.6
WSW		16.6		16.6			2	33.2	8.1
W							0	0.0	
WNW							0	0.0	
NW			16.6				1	16.6	7.9
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	16.6	16.6	49.8	16.6			6		6.9

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

100 METER LEVEL WINDS MORNING MARCH, 1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N							0	0.0	
NNE							0	0.0	
NE		12.5	12.5				2	25.0	5.0
ENE							0	0.0	
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE	12.5						1	12.5	.6
S							0	0.0	
SSW							0	0.0	
SW		25.0					2	25.0	4.5
WSW			12.5				1	12.5	6.3
W		12.5					1	12.5	4.9
WNW			12.5				1	12.5	8.6
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	12.5	50.0	37.5				8		4.9

100 METER LEVEL WINDS AFTERNOON MARCH, 1980

DIRECTION	********* WIND SPEEDS METERS/SECOND ********* 00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0	ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
N		11.1					1	11.1	4.1
NNE		11.1					1	11.1	4.7
NE		11.1					1	11.1	4.1
ENE	11.1						1	11.1	.8
E							0	0.0	
ESE							0	0.0	
SE	11.1						1	11.1	1.9
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW		33.3					3	33.3	4.5
WSW	11.1						1	11.1	2.4
W							0	0.0	
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	33.3	66.6					9		3.5

FREQUENCY SUMMARY OF UPPER LEVEL WINDS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

200 METER LEVEL WINDS MORNING MARCH, 1980

DIRECTION	********* WIND SPEEDS METERS/SECOND *********						ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0			
N	12.5						1	12.5	1.6
NNE		12.5					1	12.5	4.2
NE			12.5				1	12.5	7.5
ENE			12.5				1	12.5	6.6
E							0	0.0	
ESE							0	0.0	
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW			12.5				1	12.5	8.0
WSW			12.5				1	12.5	9.6
W		12.5					1	12.5	4.0
WNW				12.5			1	12.5	14.3
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	12.5	25.0	50.0	12.5			8		6.9

200 METER LEVEL WINDS AFTERNOON MARCH, 1980

DIRECTION	********* WIND SPEEDS METERS/SECOND *********						ROW TOTAL COUNT	SUMMARY TOTAL PERCENT	AVERAGE SPEED
	00.1 TO 02.9	03.0 TO 05.9	06.0 TO 09.9	10.0 TO 15.9	16.0 TO 25.0	GREATER THAN 25.0			
N		22.2					2	22.2	5.1
NNE							0	0.0	
NE		11.1					1	11.1	4.9
ENE							0	0.0	
E							0	0.0	
ESE	22.2						2	22.2	1.3
SE							0	0.0	
SSE							0	0.0	
S							0	0.0	
SSW							0	0.0	
SW	11.1	22.2					3	33.3	4.2
WSW							0	0.0	
W	11.1						1	11.1	2.2
WNW							0	0.0	
NW							0	0.0	
NNW							0	0.0	
CALM							0	0.0	
COL. TOTALS	44.4	55.5					9		3.6

Table 7-34

FREQUENCY SUMMARY OF INVERSIONS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

MONTH OF NOVEMBER 1978 MORNING

THICKNESS (METERS)	SFC	INVERSION BASE HEIGHT (METERS) 001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100				28.5			14.2					42.7
101-250		14.2			14.2							28.4
251-500	28.5											28.5
501-750												
TOTAL	28.5	14.2		28.5	14.2		14.2					
NO INVERSION												0.0
											TOTAL NO. OF OCCURENCES	7

INVERSION TYPE												
1				14.2			14.2					28.4
2					14.2							14.2
3	28.5	14.2										42.7
4				14.2								14.2
5												

MONTH OF NOVEMBER 1978 AFTERNOON

THICKNESS (METERS)	SFC	INVERSION BASE HEIGHT (METERS) 001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100							50.0					50.0
101-250												
251-500												
501-750												
TOTAL							50.0					
NO INVERSION												50.0
											TOTAL NO. OF OCCURENCES	1

INVERSION TYPE												
1							100.0					100.0
2												
3												
4												
5												

FREQUENCY SUMMARY OF INVERSIONS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

MONTH OF DECEMBER 1978 MORNING

THICKNESS (METERS)	SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100				16.6		16.6		16.6				49.8
101-250	33.3											33.3
251-500			16.6									16.6
501-750												
TOTAL	33.3		16.6	16.6		16.6		16.6				
NO INVERSION												0.0
								TOTAL NO. OF OCCURENCES				6

INVERSION TYPE												
1								16.6				16.6
2	16.6		16.6	16.6		16.6						66.4
3												
4	16.6											16.6
5												

MONTH OF DECEMBER 1978 AFTERNOON

THICKNESS (METERS)	SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100	33.3			33.3								66.6
101-250			33.3									33.3
251-500												
501-750												
TOTAL	33.3		33.3	33.3								
NO INVERSION												0.0
								TOTAL NO. OF OCCURENCES				3

INVERSION TYPE												
1												
2				33.3								33.3
3	33.3		33.3									66.6
4												
5												

FREQUENCY SUMMARY OF INVERSIONS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - Met.

MONTH OF JANUARY 1979 MORNING

THICKNESS (METERS)	INVERSION BASE HEIGHT (METERS) SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTA
001-100	7.6	7.6					7.6	15.3				38.1
101-250			7.6		7.6		7.6					22.8
251-500	7.6				7.6	7.6						22.8
501-750							7.6	7.6				15.2
TOTAL	15.2	7.6	7.6		15.2	7.6	22.8	22.9				
NO INVERSION												C.
								TOTAL NO. OF OCCURENCES				1
INVERSION TYPE												
1							7.6					7.6
2	7.6	7.6	7.6		15.3	7.6	15.3	7.6				68.6
3	7.6							15.3				22.9
4												
5												

MONTH OF JANUARY 1979 AFTERNOON

THICKNESS (METERS)	INVERSION BASE HEIGHT (METERS) SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTA
001-100	6.8		3.4	6.8	3.4							20.4
101-250	3.4		13.7	10.3	6.8	6.8	6.8	3.4				51.2
251-500			3.4		6.8		3.4					13.6
501-750					3.4	3.4	6.8					13.6
TOTAL	10.2		20.5	17.1	20.4	10.2	17.0	3.4				
NO INVERSION												C.
								TOTAL NO. OF OCCURENCES				2
INVERSION TYPE												
1	6.8		10.3	17.2	6.8	3.4	6.8					51.3
2	3.4		6.8		13.7	6.8	10.3	3.4				44.4
3												
4			3.4									3.4
5												

FREQUENCY SUMMARY OF INVERSIONS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - PLT.

MONTH OF MARCH 1979 MORNING

THICKNESS (METERS)	SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100			5.8	23.5	17.6		5.8					52.7
101-250	5.8	5.8		5.8	5.8							23.2
251-500	5.8					5.8	5.8					17.4
501-750												
TOTAL	11.6	5.8	5.8	29.3	23.4	5.8	11.6					
NO INVERSION												5.0
								TOTAL NO. OF OCCURENCES				16

INVERSION TYPE												
1				6.2	18.7							24.9
2		6.2	6.2	12.5			12.5					37.4
3	12.5			12.5	6.2							31.2
4						6.2						6.2
5												

MONTH OF MARCH 1979 AFTERNOON

THICKNESS (METERS)	SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100	20.0				10.0			20.0	10.0			60.0
101-250							20.0					20.0
251-500					10.0							10.0
501-750												
TOTAL	20.0				20.0		20.0	20.0	10.0			
NO INVERSION												10.0
								TOTAL NO. OF OCCURENCES				9

INVERSION TYPE												
1							22.2	22.2	11.1			55.5
2	11.1				11.1							22.2
3	11.1											11.1
4					11.1							11.1
5												

FREQUENCY SUMMARY OF INVERSIONS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

MONTH OF AUGUST 1979 MORNING

THICKNESS (METERS)	INVERSION BASE HEIGHT (METERS) SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100		9.0		27.2		9.0	9.0					54.2
101-250	9.0			18.1	9.0							36.1
251-500	9.0											9.0
501-750												
TOTAL	18.0	9.0		45.3	9.0	9.0	9.0					
NO INVERSION												0.0
									TOTAL NO. OF OCCURENCES			11

INVERSION TYPE												
1					9.0							9.0
2				36.3		9.0						45.3
3	9.0			9.0			9.0					27.0
4	9.0	9.0										18.0
5												

FREQUENCY SUMMARY OF INVERSIONS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

MONTH OF SEPTEMBER 1979 MORNING

THICKNESS (METERS)	SFC TO 100	001 TO 250	101 TO 500	251 TO 750	501 TO 1000	751 TO 1500	1001 TO 2000	1501 TO 2500	2001 TO 3000	2501 TO > THAN 3000	TOTAL
001-100		8.0		8.0	4.0		4.0	8.0			32.0
101-250	16.0		12.0	4.0	8.0	4.0					44.0
251-500	16.0		4.0								20.0
501-750											
TOTAL	32.0	8.0	16.0	12.0	12.0	4.0	4.0	8.0			
NO INVERSION											4.0
							TOTAL NO. OF OCCURENCES				24

INVERSION TYPE											
1		4.1		4.1	4.1	4.1					16.4
2	4.1	4.1	4.1	4.1	8.3		4.1				28.8
3	8.3		12.5	4.1				4.1			29.0
4	16.6										16.6
5	4.1							4.1			8.2

MONTH OF SEPTEMBER 1979 AFTERNOON

THICKNESS (METERS)	SFC TO 100	001 TO 250	101 TO 500	251 TO 750	501 TO 1000	751 TO 1500	1001 TO 2000	1501 TO 2500	2001 TO 3000	2501 TO > THAN 3000	TOTAL
001-100			10.0	20.0		10.0					40.0
101-250						10.0					10.0
251-500											
501-750											
TOTAL			10.0	20.0		20.0					
NO INVERSION											50.0
							TOTAL NO. OF OCCURENCES				5

INVERSION TYPE											
1											
2			20.0	20.0		40.0					80.0
3				20.0							20.0
4											
5											

FREQUENCY SUMMARY OF INVERSIONS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

MONTH OF OCTOBER 1979 MORNING

THICKNESS (METERS)	INVERSION BASE HEIGHT (METERS) SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100					4.5	4.5		13.6				22.6
101-250	22.7		4.5	18.1	4.5			4.5				54.3
251-500	13.6											13.6
501-750	4.5											4.5
TOTAL	40.8		4.5	18.1	9.0	4.5		18.1				
NO INVERSION												4.0
								TOTAL NO. OF OCCURENCES				21
INVERSION TYPE												
1				4.7	4.7			9.5				18.9
2			4.7	9.5		4.7		9.5				28.4
3	42.8				4.7							47.5
4				4.7								4.7
5												

MONTH OF OCTOBER 1979 AFTERNOON

THICKNESS (METERS)	INVERSION BASE HEIGHT (METERS) SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100			6.2		6.2		25.0	6.2				43.6
101-250			6.2				12.5	6.2				24.9
251-500									6.2			6.2
501-750												
TOTAL			12.4		6.2		37.5	12.4	6.2			
NO INVERSION												25.0
								TOTAL NO. OF OCCURENCES				12
INVERSION TYPE												
1			8.3		8.3		25.0	8.3	8.3			58.2
2			8.3				25.0	8.3				41.6
3												
4												
5												

FREQUENCY SUMMARY OF INVERSIONS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

MONTH OF NOVEMBER 1979 MORNING

THICKNESS (METERS)	SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100				11.1		11.1						22.2
101-250	16.6			5.5		5.5	5.5		5.5			38.6
251-500	16.6		5.5	5.5	5.5							33.1
501-750	5.5											5.5
TOTAL	38.7		5.5	22.1	5.5	16.6	5.5		5.5			
NO INVERSION												0.0
								TOTAL NO. OF OCCURENCES				18
INVERSION TYPE												
1						11.1						11.1
2				11.1	5.5	5.5	5.5		5.5			33.1
3	16.6		5.5	5.5								27.6
4	22.2			5.5								27.7
5												

MONTH OF NOVEMBER 1979 AFTERNOON

THICKNESS (METERS)	SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
001-100					11.1		5.5	5.5	16.6			38.7
101-250	16.6			11.1		5.5	16.6					49.8
251-500							5.5					5.5
501-750												
TOTAL	16.6			11.1	11.1	5.5	27.6	5.5	16.6			
NO INVERSION												5.0
								TOTAL NO. OF OCCURENCES				17
INVERSION TYPE												
1					5.8		17.6		17.6			41.0
2				11.7	5.8	5.8	11.7					35.0
3	17.6											17.6
4												
5								5.8				5.8

FREQUENCY SUMMARY OF INVERSIONS (PERCENTAGES)

LOCATION: BILLINGS - VOTECH - MAPS - MET.

MONTH OF DECEMBER 1979 MORNING

THICKNESS (METERS)	SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
	********** INVERSION BASE HEIGHT (METERS) **********											
001-100	11.5			11.5	3.8	3.8	11.5		7.6			49.7
101-250	11.5		7.6	7.6	3.8		3.8	7.6				41.9
251-500	7.6											7.6
501-750												
TOTAL	30.6		7.6	19.1	7.6	3.8	15.3	7.6	7.6			
NO INVERSION												0.0
								TOTAL NO. OF OCCURENCES				26
INVERSION TYPE												
1				3.8	3.8	3.8	7.6		7.6			26.6
2			3.8	7.6	3.8		7.6	7.6				30.4
3	11.5		3.8	3.8								19.1
4	15.3			3.8								19.1
5	3.8											3.8

MONTH OF DECEMBER 1979 AFTERNOON

THICKNESS (METERS)	SFC	001 TO 100	101 TO 250	251 TO 500	501 TO 750	751 TO 1000	1001 TO 1500	1501 TO 2000	2001 TO 2500	2501 TO 3000	> THAN 3000	TOTAL
	********** INVERSION BASE HEIGHT (METERS) **********											
001-100				16.6	16.6	8.3		8.3				49.8
101-250				8.3		16.6	8.3					33.2
251-500				8.3								8.3
501-750												
TOTAL				33.2	16.6	24.9	8.3	8.3				
NO INVERSION												8.0
								TOTAL NO. OF OCCURENCES				11
INVERSION TYPE												
1				18.1	9.0		9.0	9.0				45.1
2				9.0	9.0	27.2						45.2
3				9.0								9.0
4												
5												

The seasonal variation of elevated inversions showed the same general trend.

The temperature sonde data also were used to estimate mixing heights. Tables 8 and 9 list the frequencies of occurrence of various mixing heights by month, season, and year for mornings and afternoons. During the mornings, the mixing heights were primarily less than 250 meters, with mixing heights less than 100 meters occurring most frequently. Little seasonal variation was present. In the afternoon, mixing heights ranged from 100 to greater than 1500 meters with no mixing heights less than 100 meters. The seasonal trend showed a tendency toward lower mixing heights in the winter, whereas higher mixing heights occurred in the spring through autumn.

Summaries of the average wind speed through the mixed layer and average lapse rate below the first inversion are presented in Table 10. The data indicate slowest average wind speeds through the mixed layers during the autumn mornings with strongest average wind speeds during the late autumn and early winter afternoons. A lack of data prevented a more detailed seasonal trend. Average lapse rates below the first inversion also showed no apparent seasonal trend.

Plots of monthly average upper level temperatures, wind speeds, and wind direction were prepared and presented in Figures 6-23. The traces of temperatures reveal similar trends to that discussed in the inversion section. A surface inversion of varying strength was apparent in the morning of every month. However in the afternoons, the surface inversion was replaced by a near adiabatic lapse rate. (See definition in the Glossary.)

The acoustic radar located at the Billings-Vo-Tech site provided data on mixing heights; inversion height, thickness, and duration; and relative stability (see Gelhaus, 1979). A review of the first inversion's (inversion nearest

TABLE 8
Billings - Votech
Mixing Heights - Number of Occurrences
1978 - 80
Morning

Height (m)	J	F	M	A	M	J	J	A	S	O	N	D	S	S	F	W	A
0 - 100	5	5	6	8				4	7	7	9	6	14	4	23	16	57
101-250	6	5	4	1				2	2	6	1	2	5	2	9	13	29
251-500	1	1	3	0				2	0	2	0	2	3	2	2	4	11
501-750	0	3	2	0				0	0	0	0	1	2	0	0	4	6
751-1000	1	1	0	1				0	0	1	0	0	1	0	1	2	4
1001-1500	0	0	2	0				0	0	0	0	0	2	0	0	0	2
>1500	0	1	0	0				1	0	0	0	0	0	1	0	1	2
TOTAL	13	16	17	10	-	-	-	9	9	16	10	11	27	9	35	40	111

TABLE 9
Billings - Votech
Mixing Heights - Number of Occurrences
1978 - 80
Afternoon

Height (m)	J	F	M	A	M	J	J	A	S	O	N	D	S	S	F	W	A
0 - 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101-250	7	5	2	0				3	1	1	0	0	2	3	2	12	19
251-500	6	1	1	1				1	1	0	0	3	2	1	1	10	14
501-750	2	0	8	1				0	1	1	3	1	9	0	5	3	17
751-1000	0	3	2	0				0	1	1	0	1	2	0	2	4	8
1001-1500	1	1	0	2				1	2	3	1	1	2	1	6	3	12
>1500	1	1	7	3				4	7	12	1	0	10	4	20	2	36
TOTAL	17	11	20	7	-	-	-	9	13	18	5	6	27	9	26	34	106

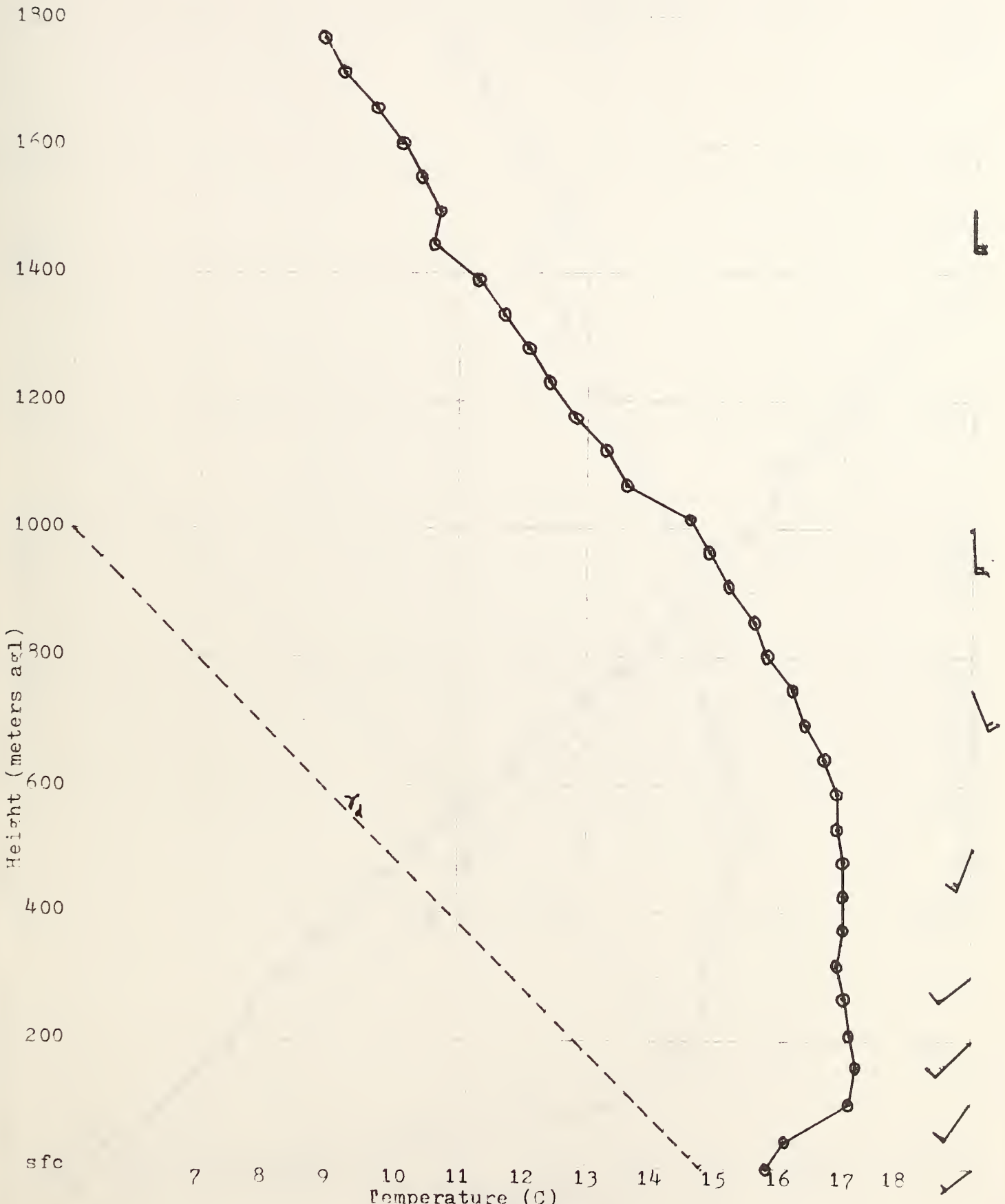
TABLE 10

Billings - VoTech
Mixed Layer Wind and Lapse Rate Summary

	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Aver. Wind Speed Thru Mixed Layer (m/sec)	5.4	4.0	7.2	3.4	-	-	-	4.2	3.4	5.6	4.6	9.0	5.5	7.8	5.8	7.6	-	-	-	4.3	5.4	9.6	10.3	10.7
Aver. Lapse Rate Below 1st Inversion (deg. c/m)	-.68	-.82	-.78	-.38	-	-	-	-.47	-.00	-.00	-.00	-.00	-.65	-.81	-.92	-1.18	-	-	-	-.00	-1.39	-1.15	-.46	-.66

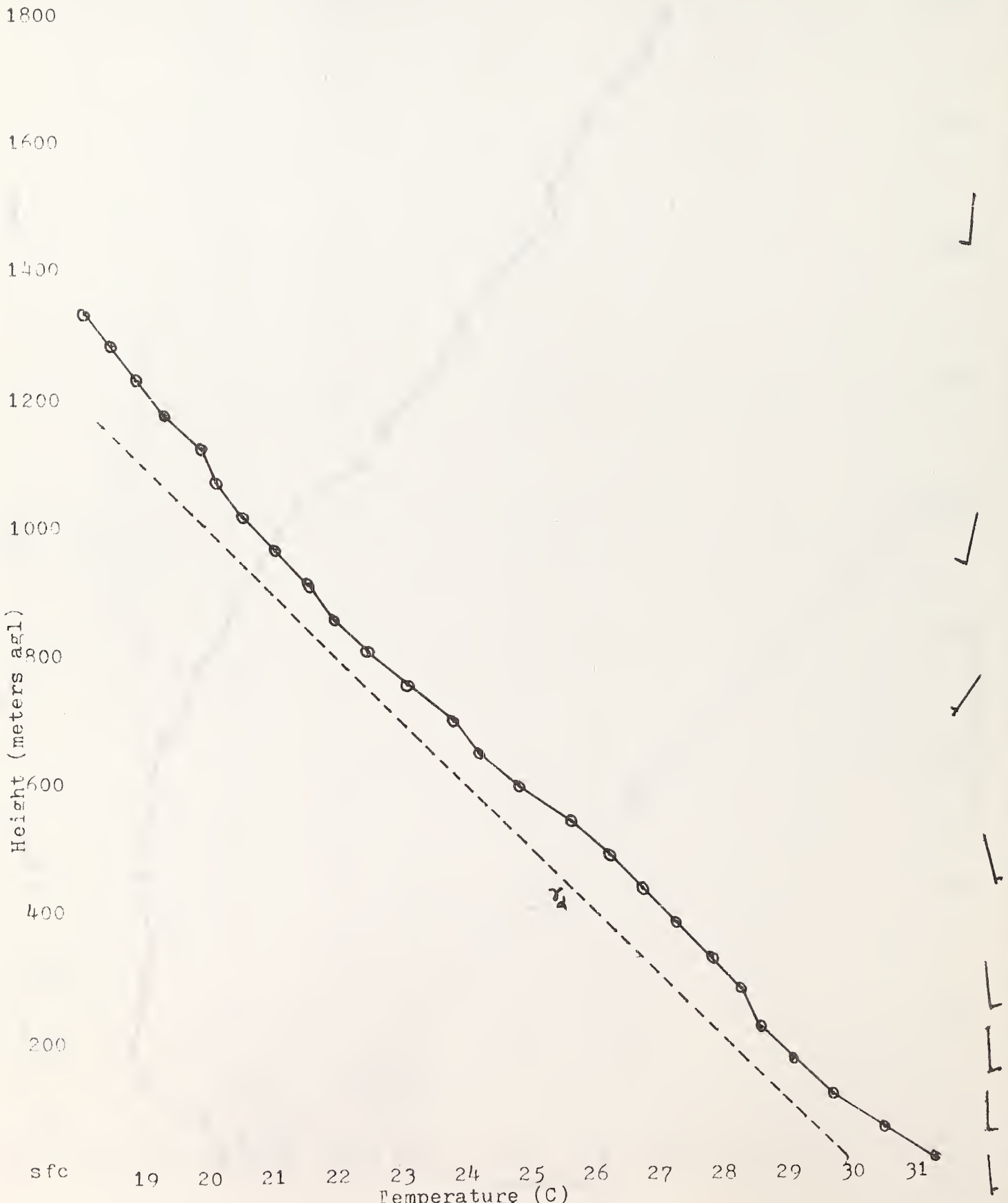
Morning Monthly Average Upper Air Sounding
Billings, MT August 1979

Figure 6



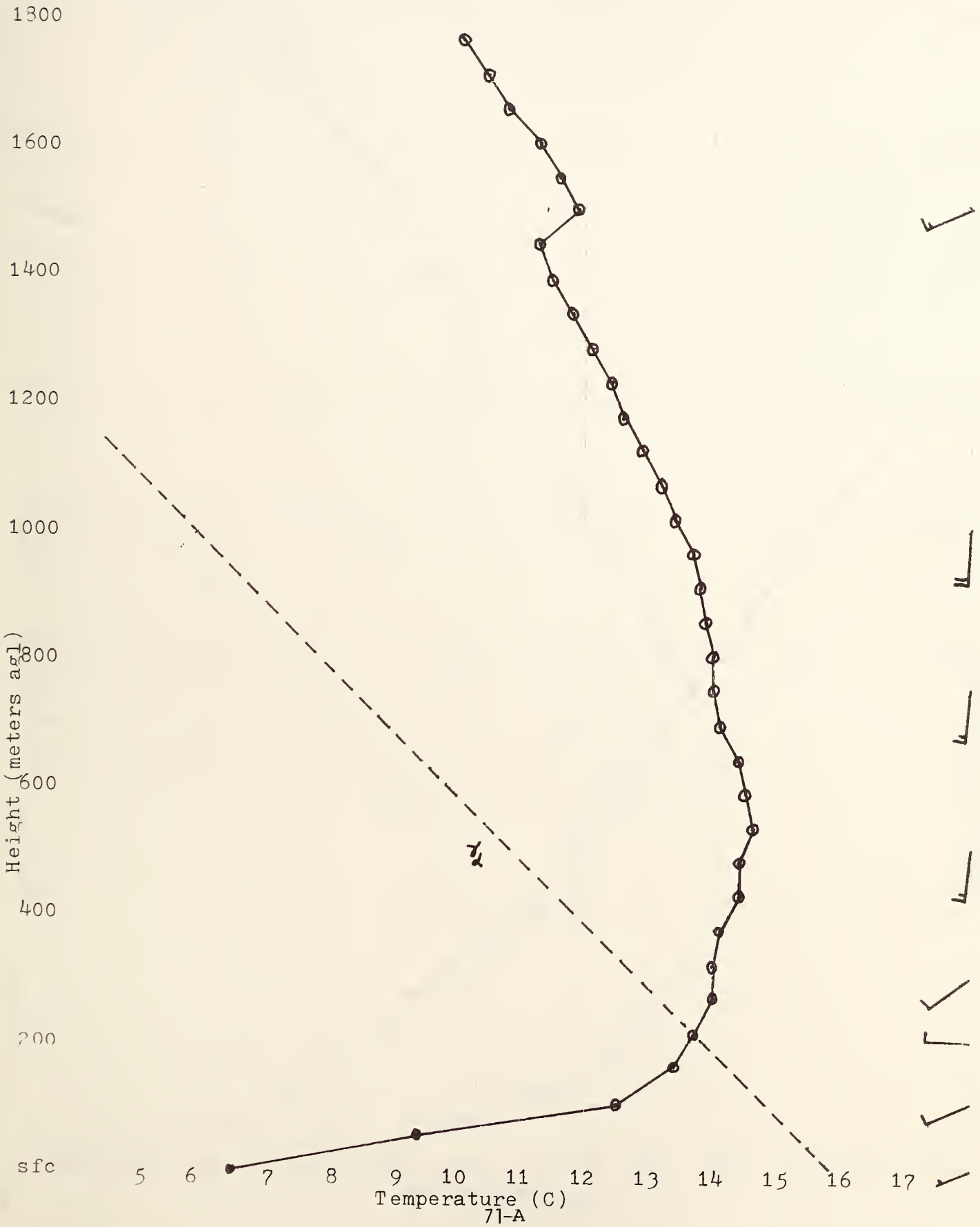
Afternoon Monthly Average Upper Air Sounding
Billings, MT August 1979

Figure 7



Morning Monthly Average Upper Air Sounding
Billings, MT September 1979

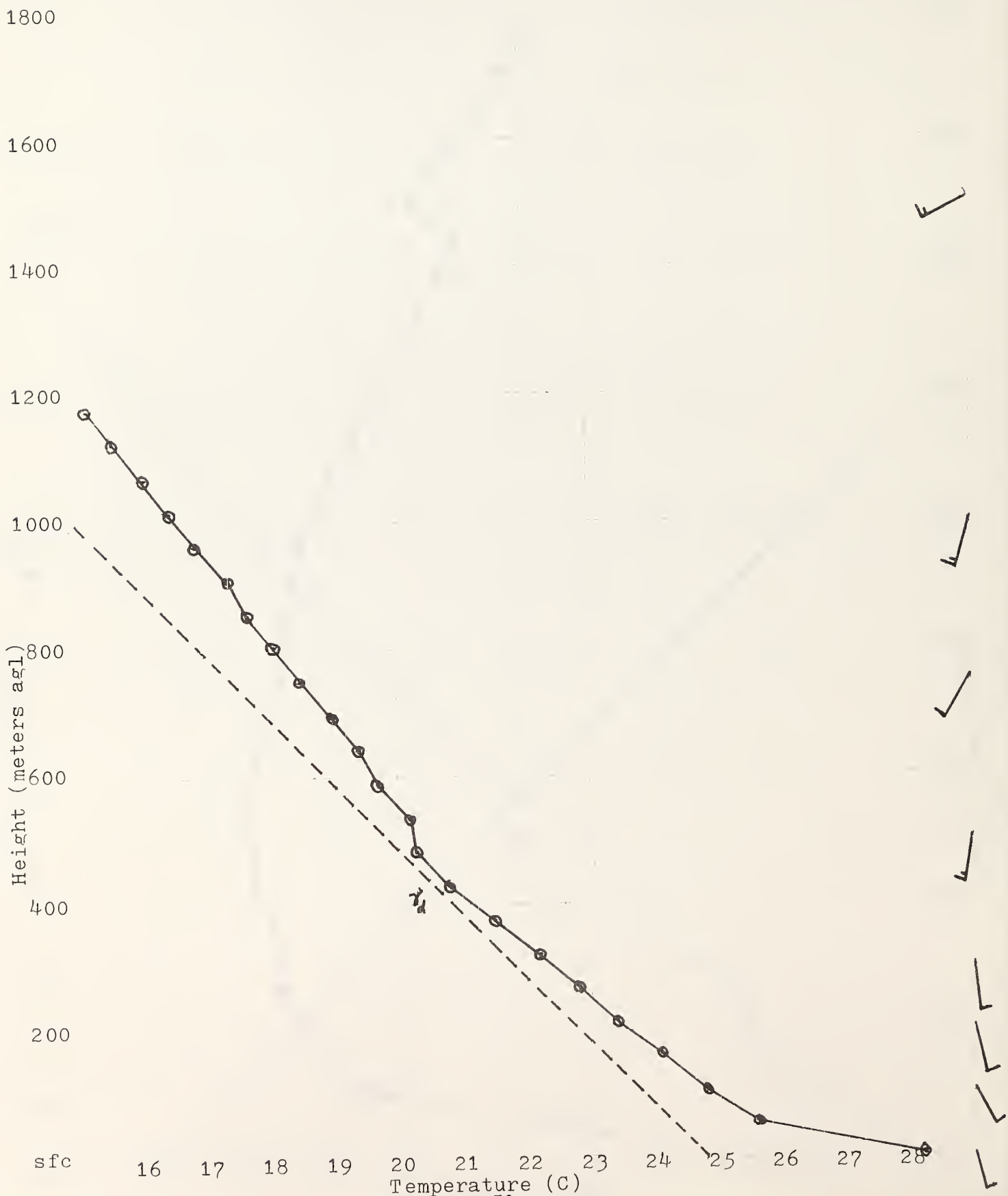
Figure 8



71-A

Afternoon Monthly Average Upper Air Sounding
Billings, MT September 1979

Figure 9

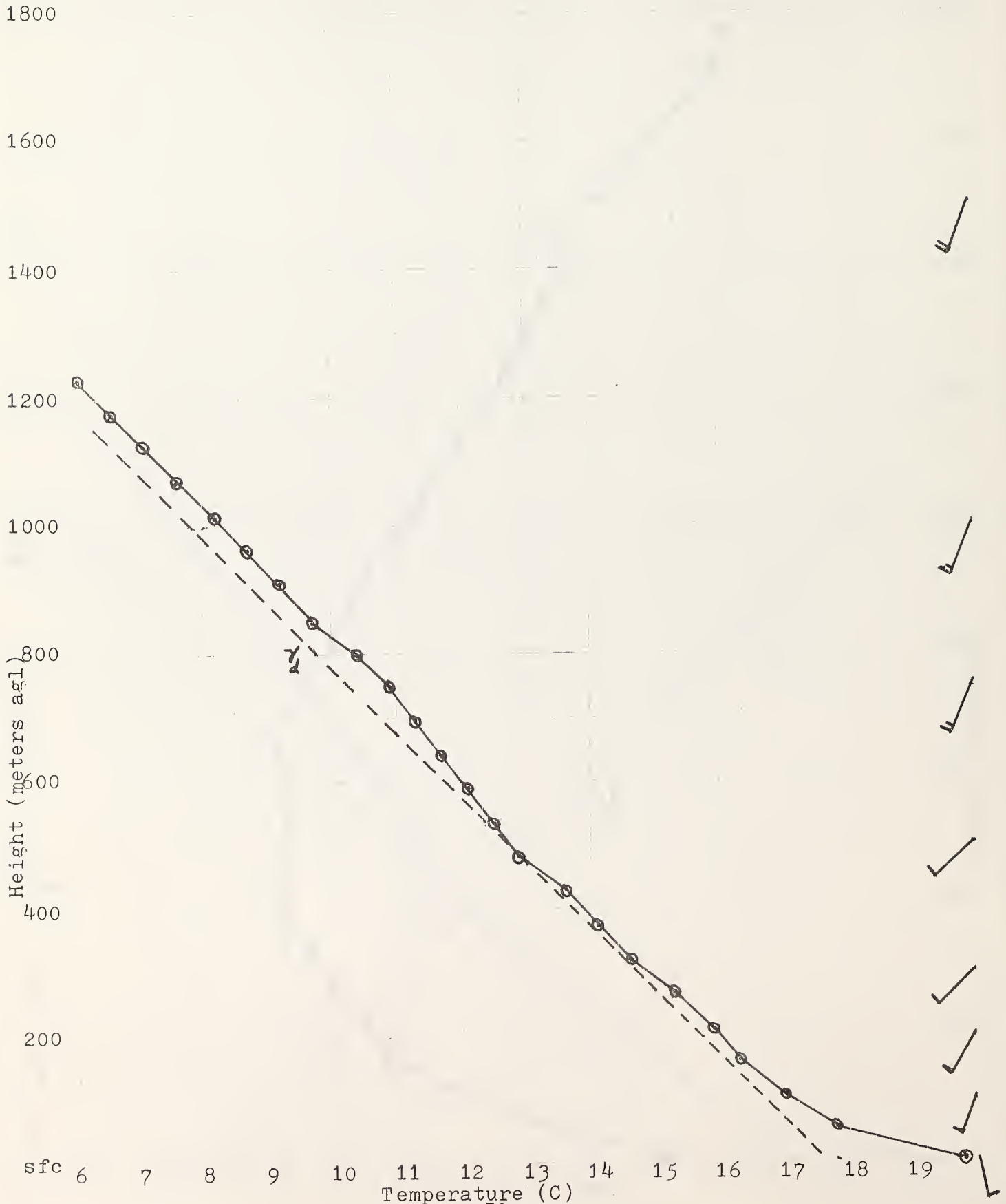


Morning Monthly Average Upper Air Sounding
Billings, MT October 1979

Figure 10

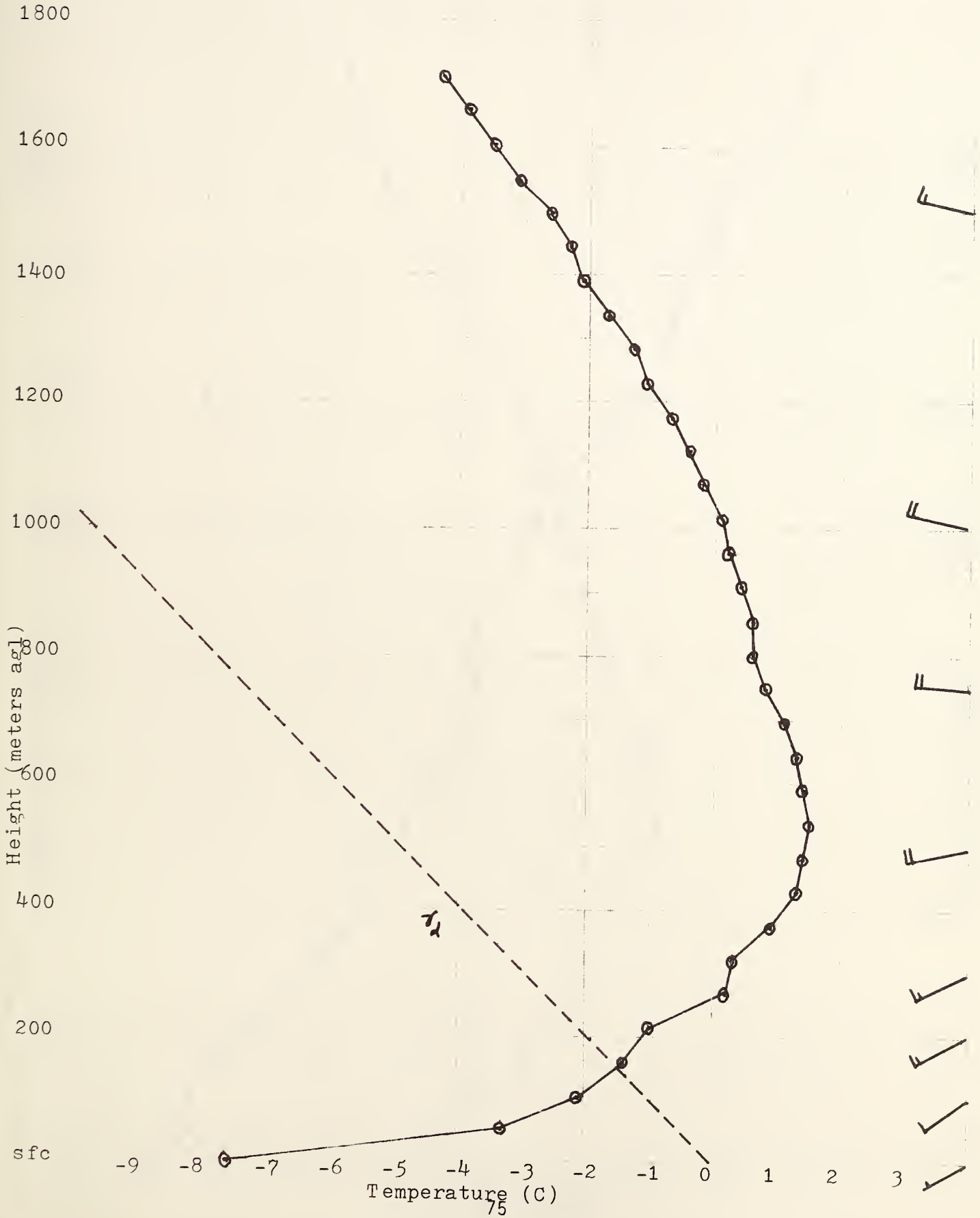
Afternoon Monthly Average Upper Air Sounding
Billings, MT October 1979

Figure 11



Morning Monthly Average Upper Air Sounding
Billings, MT November 1979

Figure 12

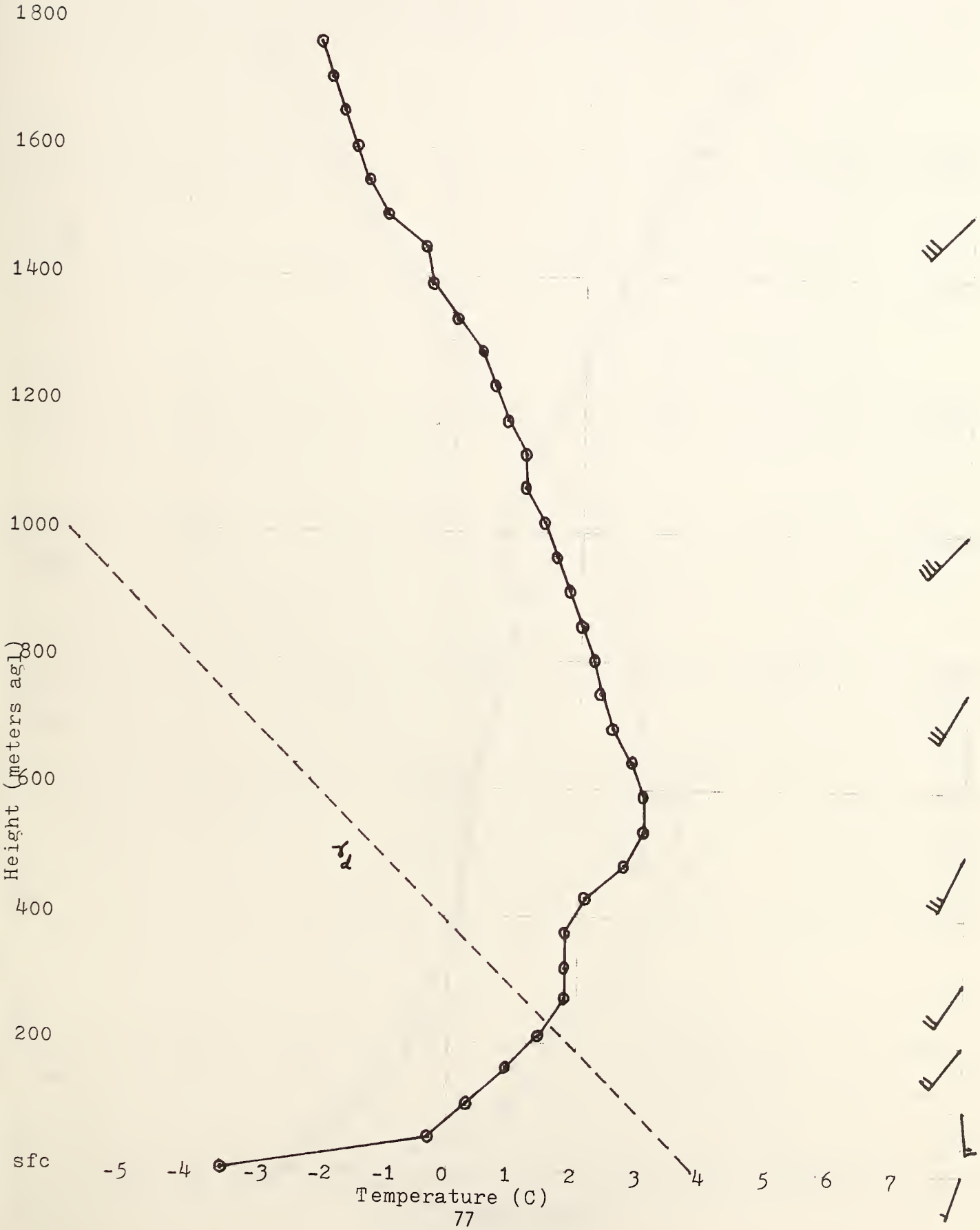


Afternoon Monthly Average Upper Air Sounding
Billings, MT November 1979

Figure 13

Morning Monthly Average Upper Air Sounding
Billings, MT December 1979

Figure 14

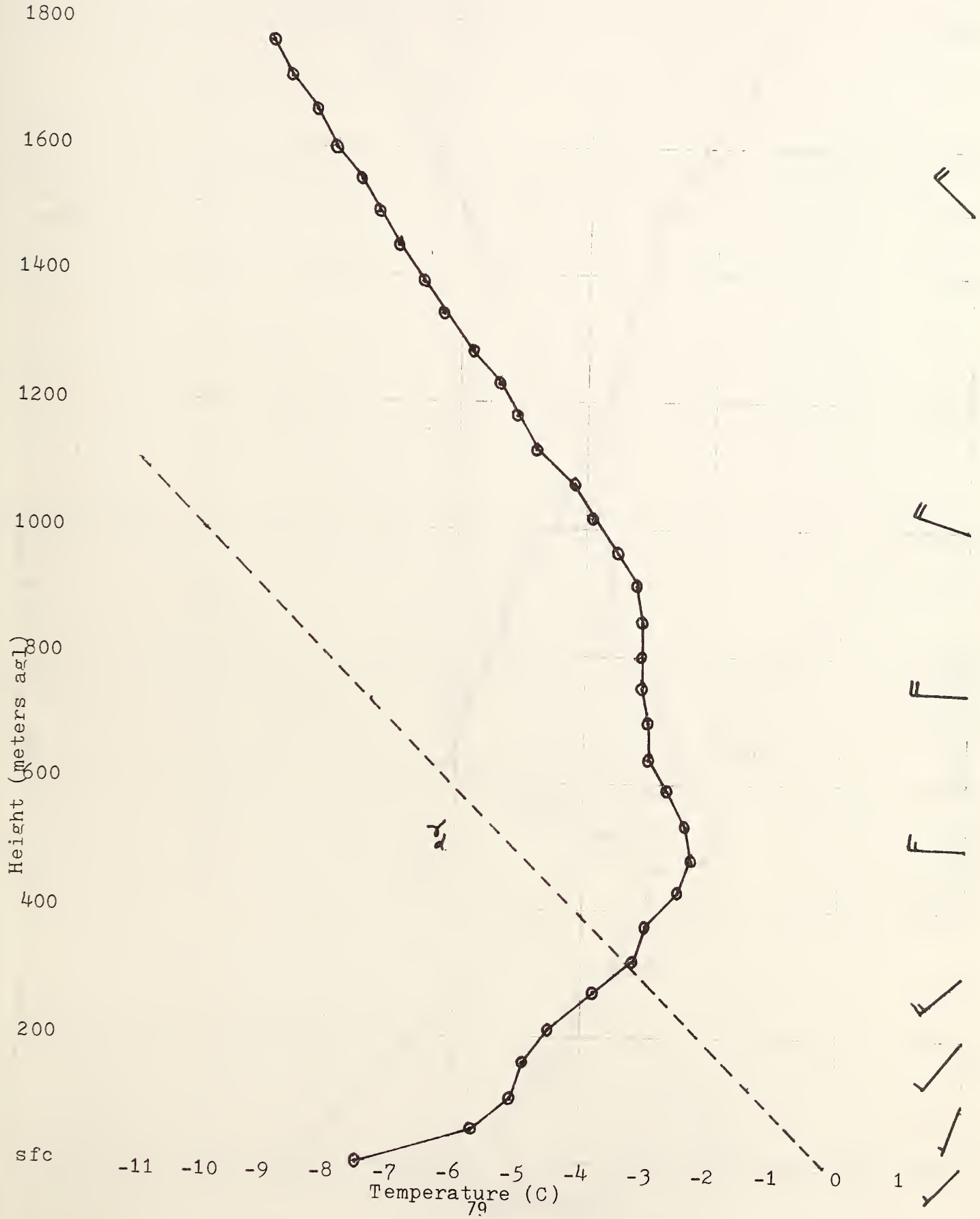


Afternoon Monthly Average Upper Air Sounding
Billings, MT December 1979

Figure 15

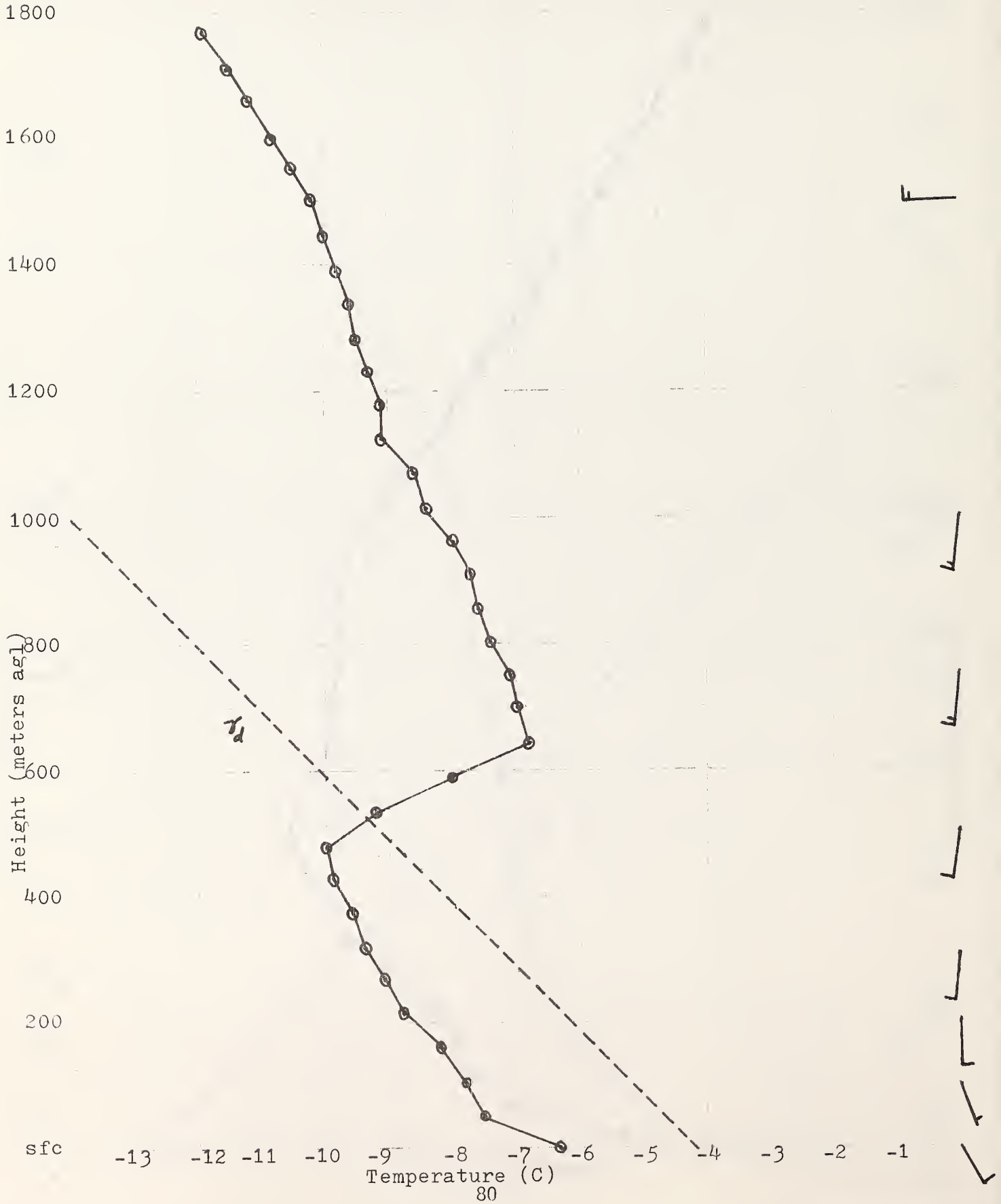
Morning Monthly Average Upper Air Sounding
Billings, MT January 1980

Figure 16



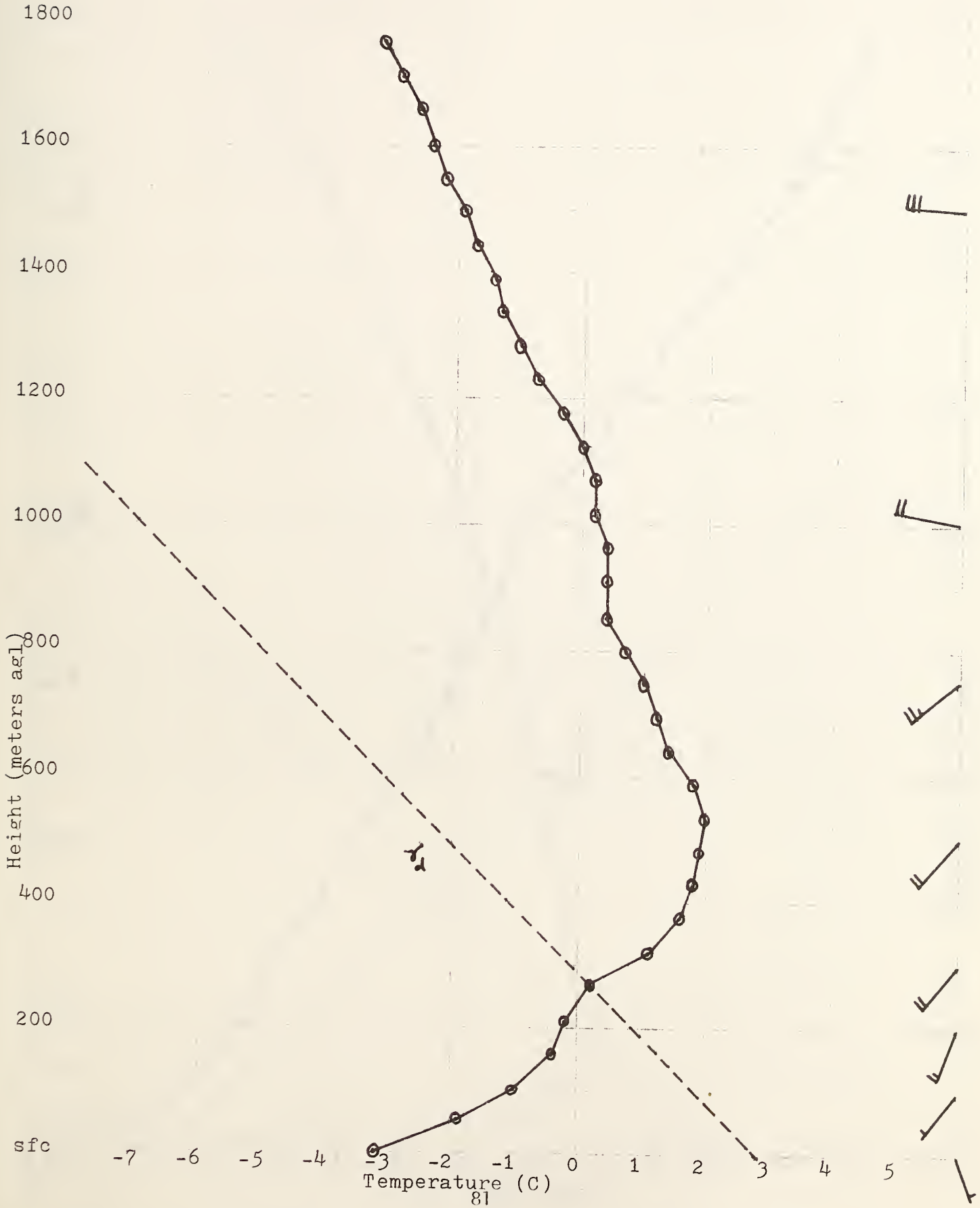
Afternoon Monthly Average Upper Air Sounding
Billings, MT January 1980

Figure 17



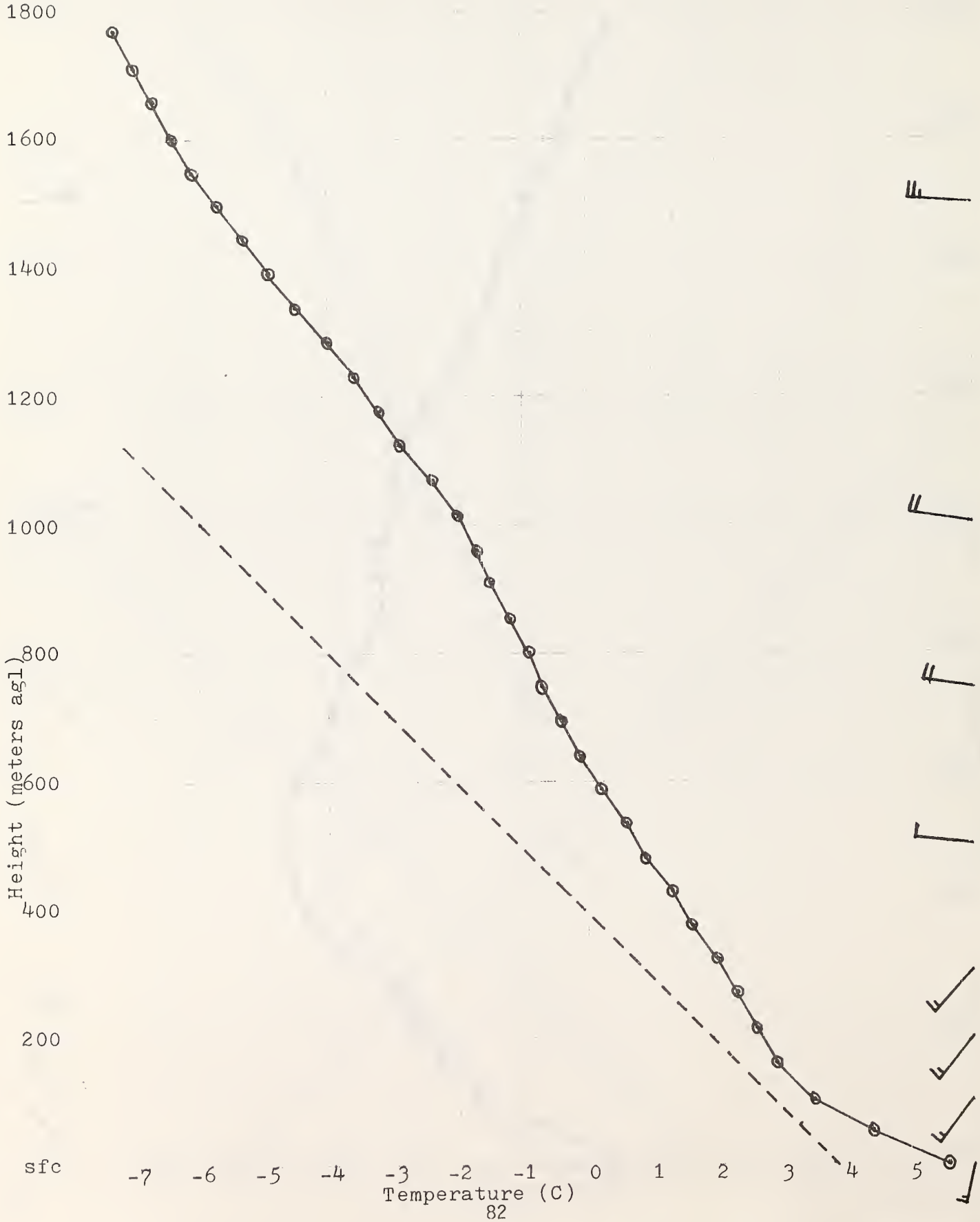
Morning Monthly Average Upper Air Sounding
Billings, MT February 1980

Figure 18



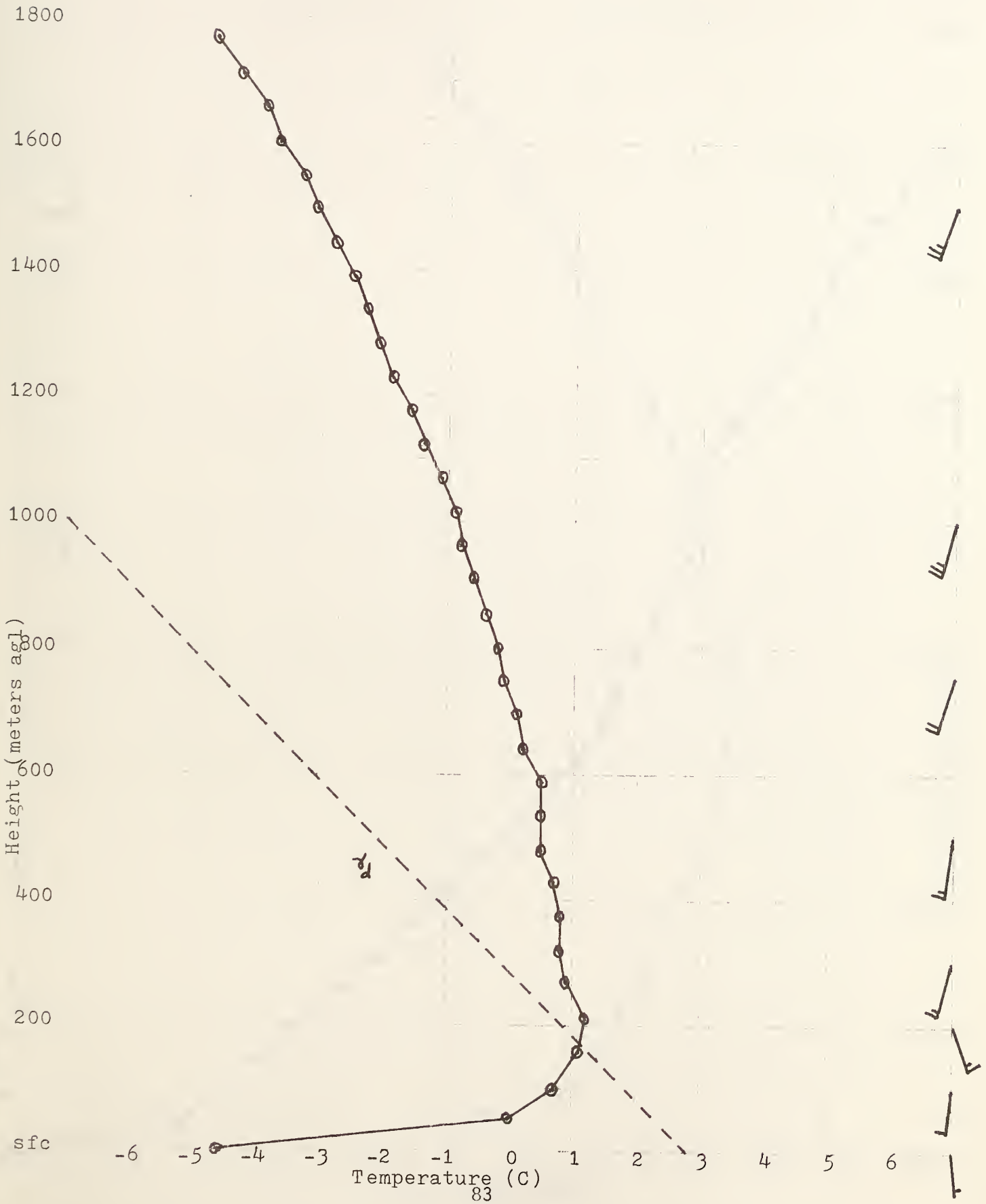
Afternoon Monthly Average Upper Air Sounding
Billings, MT February 1980

Figure 19



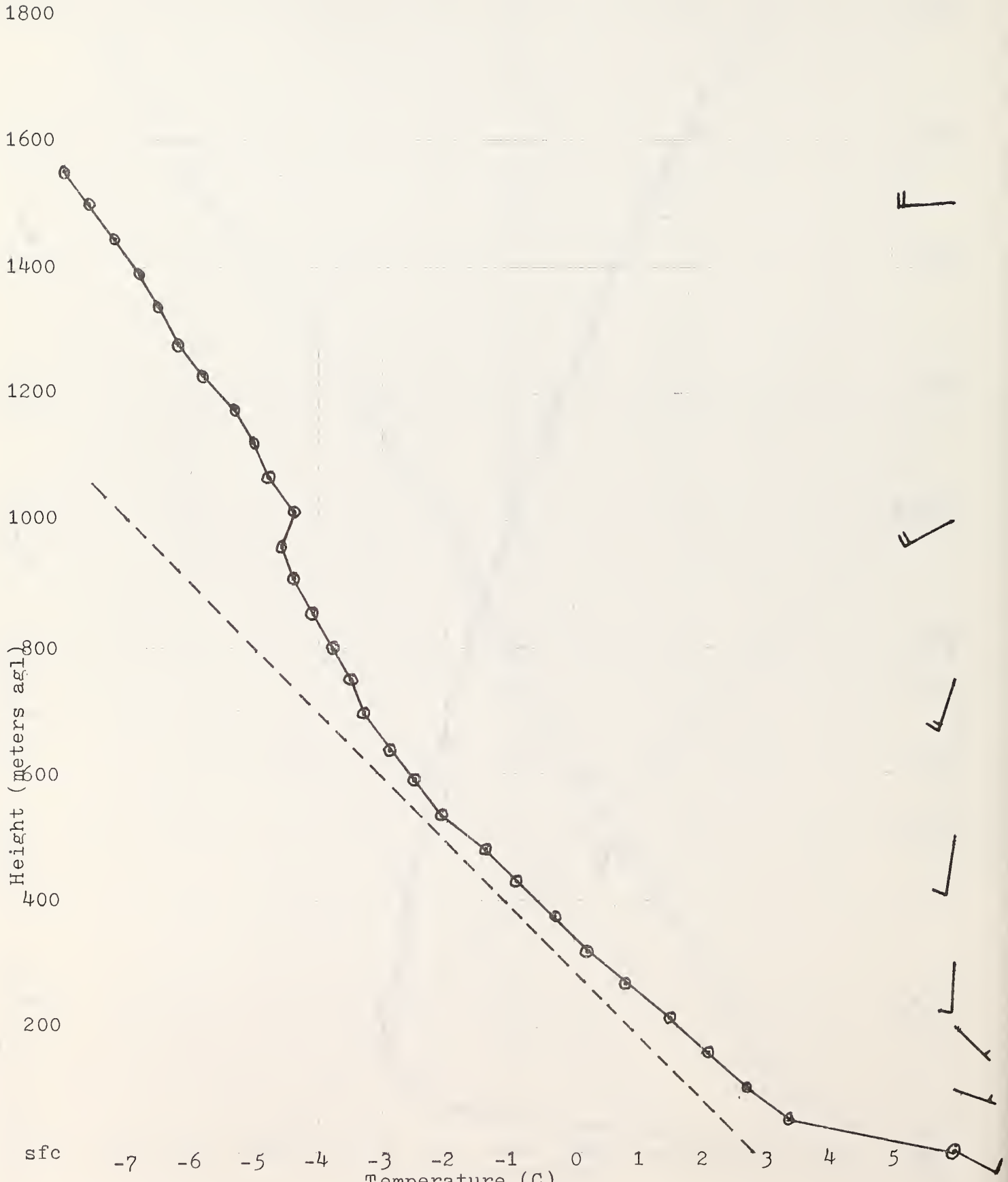
Morning Monthly Average Upper Air Sounding
Billings, MT March 1980

Figure 20



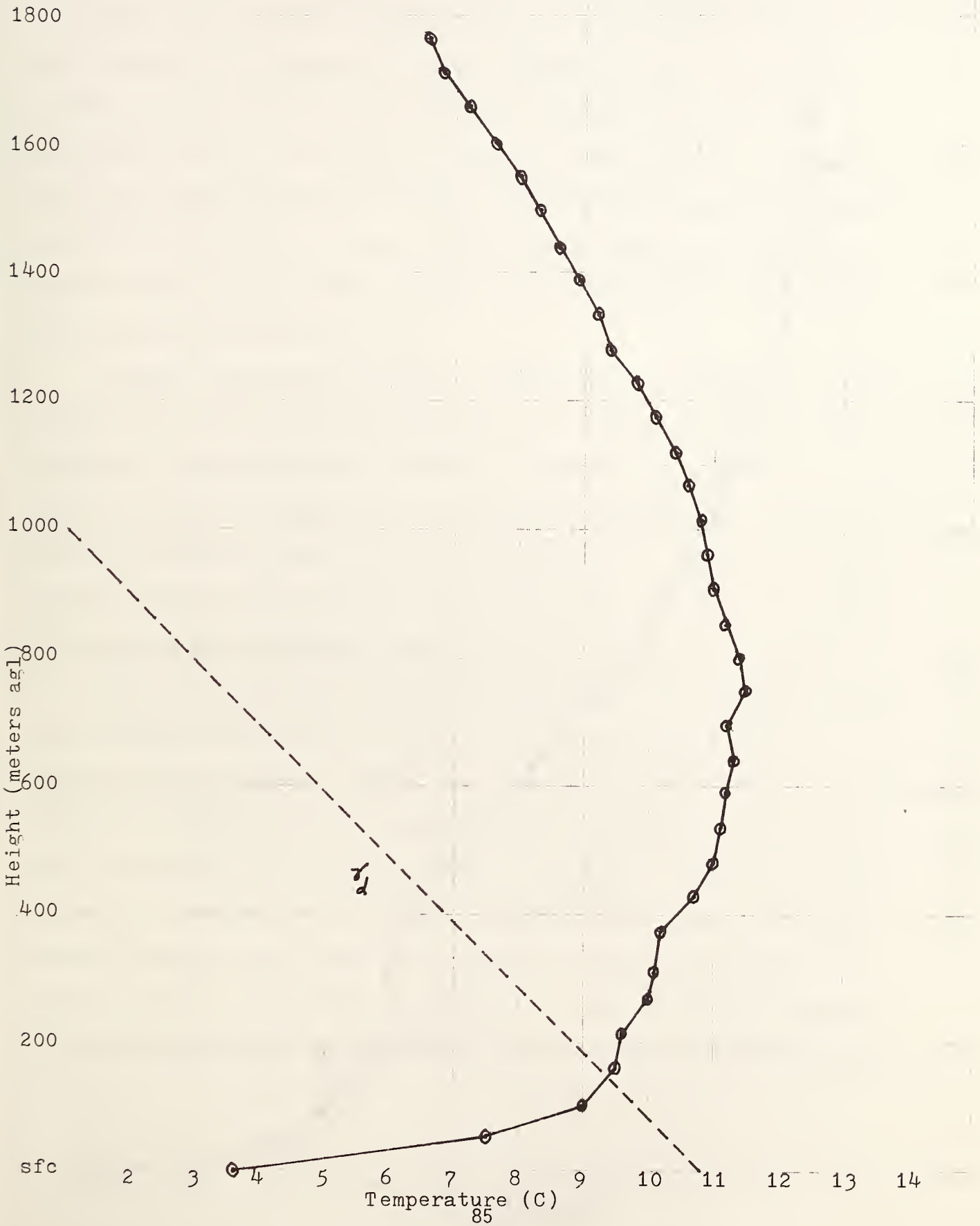
Afternoon Monthly Average Upper Air Sounding
Billings, MT March 1980

Figure 21



Morning Monthly Average Upper Air Sounding
Billings, MT April 1980

Figure 22



Afternoon Monthly Average Upper Air Sounding
Billings, MT April 1980

Figure 23

the surface) frequency of occurrence revealed that surface inversions between 100 and 300 meters thick were most common during all months. Inversions were present most of the time during hours of darkness, but seldom present during the afternoon. The frequency of occurrence among nocturnal inversions was similar from month to month, but afternoon inversions were more common in the winter months, although they occurred less than 20 percent of the time. The period 0600-1200 Mountain Standard Time (MST) showed the greatest seasonal variation in inversion frequency, with inversions being more than twice as common during the winter than the autumn. This is probably a consequence of the shorter days during the winter.

Elevated inversions and second inversions were very uncommon. There also did not appear to be any significant monthly or seasonal variation in the frequency of those inversions. The lack of elevated inversions differs somewhat with that of the temperature sonde data, which showed weak and shallow elevated inversions present. The lack of evidence as to these elevated inversions present on the radar data is probably due to the radar's inability to detect the weak and shallow inversions.

A two-hour stability analysis was performed based on the acoustic radar data, together with cloud cover from the NWS and wind speed data from the Central Park site (Gelhaus, 1979b). See Table 11. For this analysis, stability categories ranging from A (very unstable) to F (moderately stable) were computed for two-hour time intervals throughout the months. During all months, categories D (neutral) and E (slightly stable) were most common. The least common categories were A (very unstable) and B (moderately unstable). The diurnal variation in stability was similar from month to month with the most stable conditions occurring at night and the most unstable conditions occurring

TABLE 11
FREQUENCY OF OCCURRENCE OF STABILITY CATEGORIES
Billings Votech Site

Month/Year	Stability Category (Percentage Occurrence) A	B	C	D	E	F
September 1978	0.0	0.3	16.7	33.6	20.6	4.2
October	0.0	0.3	19.9	33.1	37.9	7.8
November	0.0	0.0	4.4	14.7	21.4	0.6
December	0.0	0.0	0.3	32.0	54.0	1.9
January 1979	0.0	0.0	0.0	45.2	36.0	8.3
February	0.0	0.0	0.6	45.8	39.0	4.5
March						
April						
May	0.0	0.5	13.4	7.5	12.1	5.4
June						
July						
August						
September						
October						
November						
December						
January 1980	0.0	1.6	22.6	27.2	44.1	4.6
February	0.0	1.2	19.2	19.0	46.4	7.4
March	0.0	0.0	19.4	26.6	37.4	7.8
April	0.0	0.0	24.7	28.1	33.3	7.8

at night and the most unstable conditions occurring during the afternoon. The transitions between nighttime and daytime conditions generally occurred within two hours after sunrise and sunset.

The frequency of occurrence of the various stability categories versus wind speed and wind direction (star frequency or stability rose) also is presented in Table 12. These data are presented for information only, as frequently these data are needed to conduct dispersion modeling.

TABLE 12
Stability Rose Summary*
Billings, Montana

Stability Class A
Wind Speed Category (m/sec)

Wind Direction	0.67	2.45	4.47	6.93	9.61	12.52
N	0.000	0.000	0.000	0.000	0.000	0.000
NNE	0.000	0.000	0.000	0.000	0.000	0.000
NE	0.000	0.000	0.000	0.000	0.000	0.000
ENE	0.000	0.000	0.000	0.000	0.000	0.000
E	0.000	0.000	0.000	0.000	0.000	0.000
ESE	0.000	0.000	0.000	0.000	0.000	0.000
SE	0.000	0.000	0.000	0.000	0.000	0.000
SSE	0.000	0.000	0.000	0.000	0.000	0.000
S	0.000	0.000	0.000	0.000	0.000	0.000
SSW	0.000	0.000	0.000	0.000	0.000	0.000
SW	0.000	0.000	0.000	0.000	0.000	0.000
WSW	0.000	0.000	0.000	0.000	0.000	0.000
W	0.000	0.000	0.000	0.000	0.000	0.000
WNW	0.000	0.000	0.000	0.000	0.000	0.000
NW	0.000	0.000	0.000	0.000	0.000	0.000
NNW	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 12 (Continued)
Stability Rose Summary *
Billings, Montana

Stability Class B
Wind Speed Category (m/sec)

Wind Direction	0.67	2.45	4.47	6.93	9.61	12.52
N	0.000	0.000	0.000	0.000	0.000	0.000
NNE	0.000	0.000	0.000	0.000	0.000	0.000
NE	0.000	0.000	0.000	0.000	0.000	0.000
ENE	0.001	0.000	0.000	0.000	0.000	0.000
E	0.000	0.000	0.000	0.000	0.000	0.000
ESE	0.001	0.000	0.000	0.000	0.000	0.000
SE	0.000	0.000	0.000	0.000	0.000	0.000
SSE	0.000	0.000	0.000	0.000	0.000	0.000
S	0.000	0.000	0.000	0.000	0.000	0.000
SSW	0.001	0.000	0.000	0.000	0.000	0.000
SW	0.001	0.000	0.000	0.000	0.000	0.000
WSW	0.000	0.000	0.000	0.000	0.000	0.000
W	0.001	0.000	0.000	0.000	0.000	0.000
WNW	0.000	0.000	0.000	0.000	0.000	0.000
NW	0.000	0.000	0.000	0.000	0.000	0.000
NNW	0.000	0.000	0.000	0.000	0.000	0.000

TABLE 12(Continued)
Stability Rose Summary *
Billings, Montana

Stability Class C
Wind Speed Category (m/sec)

Wind Direction	0.67	2.45	4.47	6.93	9.61	12.52
N	0.002	0.004	0.001	0.000	0.000	0.000
NNE	0.001	0.003	0.000	0.000	0.000	0.000
NE	0.006	0.004	0.000	0.000	0.000	0.000
ENE	0.006	0.004	0.000	0.000	0.000	0.000
E	0.005	0.005	0.001	0.000	0.000	0.000
ESE	0.003	0.002	0.003	0.000	0.000	0.000
SE	0.005	0.005	0.002	0.000	0.000	0.000
SSE	0.003	0.001	0.000	0.000	0.000	0.000
S	0.005	0.001	0.000	0.000	0.000	0.000
SSW	0.003	0.001	0.000	0.000	0.000	0.000
SW	0.003	0.002	0.000	0.000	0.000	0.000
WSW	0.008	0.007	0.006	0.001	0.000	0.000
W	0.011	0.017	0.014	0.003	0.000	0.000
WNW	0.004	0.006	0.009	0.005	0.000	0.000
NW	0.003	0.002	0.003	0.000	0.000	0.000
NNW	0.002	0.004	0.003	0.000	0.000	0.000

TABLE 12 (Continued)
Stability Rose Summary *
Billings, Montana

Stability Class D
Wind Speed Category (m/sec)

Wind Direction	0.67	2.45	4.47	6.93	9.61	12.52
N	0.006	0.010	0.004	0.000	0.000	0.000
NNE	0.009	0.008	0.001	0.000	0.000	0.000
NE	0.018	0.009	0.000	0.000	0.000	0.000
ENE	0.013	0.008	0.001	0.000	0.000	0.000
E	0.008	0.005	0.002	0.000	0.000	0.000
ESE	0.004	0.004	0.002	0.000	0.000	0.000
SE	0.004	0.004	0.002	0.000	0.000	0.000
SSE	0.004	0.000	0.000	0.000	0.000	0.000
S	0.003	0.000	0.000	0.000	0.000	0.000
SSW	0.004	0.000	0.000	0.000	0.000	0.000
SW	0.007	0.001	0.001	0.001	0.000	0.000
WSW	0.011	0.010	0.002	0.002	0.000	0.000
W	0.021	0.027	0.025	0.010	0.001	0.000
WNW	0.009	0.008	0.010	0.004	0.001	0.000
NW	0.005	0.005	0.007	0.003	0.000	0.000
NNW	0.003	0.006	0.005	0.001	0.001	0.000

TABLE 12 (Continued)
Stability Rose Summary *
Billings, Montana

Stability Class E
Wind Speed Category (m/sec)

Wind Direction	0.67	2.45	4.47	6.93	9.61	12.52
N	0.009	0.001	0.001	0.000	0.000	0.000
NNE	0.008	0.001	0.000	0.000	0.000	0.000
NE	0.009	0.002	0.000	0.000	0.000	0.000
ENE	0.010	0.001	0.000	0.000	0.000	0.000
E	0.014	0.002	0.000	0.000	0.000	0.000
ESE	0.008	0.002	0.001	0.000	0.000	0.000
SE	0.008	0.002	0.001	0.000	0.000	0.000
SSE	0.006	0.000	0.000	0.000	0.000	0.000
S	0.006	0.000	0.000	0.000	0.000	0.000
SSW	0.014	0.000	0.000	0.000	0.000	0.000
SW	0.027	0.002	0.000	0.000	0.000	0.000
WSW	0.057	0.019	0.007	0.001	0.000	0.000
W	0.056	0.050	0.034	0.005	0.000	0.000
WNW	0.024	0.016	0.011	0.001	0.000	0.000
NW	0.009	0.003	0.001	0.000	0.000	0.000
NNW	0.009	0.004	0.001	0.000	0.000	0.000

TABLE 12 (Continued
Stability Rose Summary *
Billings, Montana

Stability Class F
Wind Speed Category (m/sec)

Wind Direction	0.67	2.45	4.47	6.93	9.61	12.52
N	0.002	0.000	0.000	0.000	0.000	0.000
NNE	0.002	0.000	0.000	0.000	0.000	0.000
NE	0.003	0.001	0.000	0.000	0.000	0.000
ENE	0.003	0.000	0.000	0.000	0.000	0.000
E	0.004	0.000	0.000	0.000	0.000	0.000
ESE	0.001	0.000	0.000	0.000	0.000	0.000
SE	0.001	0.000	0.000	0.000	0.000	0.000
SSE	0.001	0.000	0.000	0.000	0.000	0.000
S	0.000	0.000	0.000	0.000	0.000	0.000
SSW	0.002	0.000	0.000	0.000	0.000	0.000
SW	0.003	0.000	0.000	0.000	0.000	0.000
WSW	0.004	0.000	0.000	0.000	0.000	0.000
W	0.007	0.001	0.000	0.000	0.000	0.000
WNW	0.003	0.000	0.000	0.000	0.000	0.000
NW	0.001	0.001	0.000	0.000	0.000	0.000
NNW	0.001	0.000	0.000	0.000	0.000	0.000

*STABILITY ROSE SUMMARY
Billings, Montana

Surface Wind Site: Central Park
Stability Data Site:Votech Center

Start Date of Data: August 10, 1978
End Date of Data: May 8, 1980

Number of Days Which Had Some Data: 533
Number of Hours Not Used Due to Missing Wind Data: 4140
Number of Hours Not Used Due to Missing Stability Data: 2476
Number of Hours Not Used Due to Zero Wind Speed: 642
Number of Hours of Data Used To Generate Stability Rose Summary: 5220

IV. SUMMARY

The meteorological study, in addition to providing support to health effects, air quality, or modeling studies, has provided valuable information on the surface and upper air meteorological patterns of the Billings urban area. Billings' location about fifty miles northeast of the Rocky Mountains is the most important factor influencing the wind patterns of the area. Foehn-type or "chinook" winds blowing from the mountains ensure that the prevailing wind direction is westerly throughout the year. Of major importance also is the Yellowstone River Valley, which in this area is oriented southwest through northeast and averages ten miles wide and about 300 feet deep. Frequent calm or near calm wind speeds coupled with shallow mixing heights, especially during darkness and early morning hours, tend to stagnate air pollution emissions in the Billings area. Generally, the wind speeds increase and mixing heights deepen in the afternoons to remove or disperse the air pollutants.

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GLOSSARY

The following terms were taken from the Glossary of Terms Frequently Used in Air Pollution, published by the American Meteorological Society.

ADIABATIC LAPSE RATE - The change of temperature with height of a parcel of dry air if it is lifted or lowered, with no loss or gain of heat.

AIR POLLUTION - The general term alluding to the undesirable addition to the atmosphere of substances (gases and liquids and solid particles) either that are foreign to the "natural" atmosphere or in quantities exceeding their natural concentrations.

AIR QUALITY - The composition of air with respect to quantities of pollutants therein; used most frequently in connection with "standards" of maximum acceptable pollutant concentrations.

ATMOSPHERIC PRESSURE - (Also called barometric pressure) The pressure exerted by the atmosphere as a consequence of gravitational attraction exerted upon the "column" of air lying directly above the point in question. As with any gas, the pressure exerted by the atmosphere is ultimately explainable in terms of bombardment by gas molecules; it is independent of the orientation of the surface on which it acts.

Atmospheric pressure is one of the basic meteorological elements. It is measured by many varieties of barometer, and is expressed in several units systems. The most common unit used is the millibar (1 millibar equals 1000 dynes per cm^2). Unique to the science of meteorology is the use of inches (or millimeters) of mercury; that is, the height of a column of mercury that exactly balances the weight of the column of atmosphere whose base coincides with that of the mercury column. Also employed are units of weight per area and units of force per area. A standard atmosphere has been defined in terms of equivalence to each of the above unit systems, and it is used as a unit itself.

CIRCULATION PATTERN - The general geometric configuration of atmospheric circulation at a given time and region.

CLEAN AIR - A political term alluding to the chemical and optical condition of the atmosphere back in the good old days.

DEW POINT - (Or dew point temperature). The temperature to which a given parcel of air must be colled at constant pre-sure and constant water-vapor content in order for saturation to occur.

FREE LIFT - The actual lifting force of an inflated balloon, usually expressed in grams. The free lift plus the weight of the balloon and attached equipment is the total lift.

INVERSION - In meteorology, a departure from the usual decrease or increase with altitude of the atmospheric property; also, the layer through which this departure occurs (the "inversion layer") or the lowest altitude at which the departure is found (the "base of the inversion"). This term almost always means a temperature inversion.

INVERSION LAYER - A layer in the atmosphere through which the temperature remains constant or increases with altitude.

LAPSE RATE - The change in an atmospheric variable, usually temperature, with height.

MIXING HEIGHT - (Or mixing depth) The thickness of the atmospheric layer, measured from the surface upward, through which pollutants are presumed to mix by virtue of convection caused by daytime heating at the surface. The designation of mixing height implies the existence of an inversion, in which case the mixing height is also the height of the inversion base.

PILOT BALLOON - A small balloon whose ascent is followed by a theodolite in order to obtain data for the computation of the speed and direction of winds in the upper air.

PILOT-BALLOON OBSERVATION - (Commonly contracted pibal) A method of winds-aloft observation; that is, the determination of wind speeds and directions in atmosphere above a station. This is done by reading the elevation and azimuth angles of a theodolite while visually tracking a pilot balloon.

The ascension rate of the balloon is approximately determined by careful inflation to a given total lift. After release from the ground, periodic readings (ususally at one-minute intervals) of elevation and azimuth angles of the balloon are recorded. These data are transferred to a winds-aloft plotting board, and the wind speed and direction at selected levels are calculated by trigonometric methods.

PREVAILING WIND DIRECTION - (Or prevailing wind) The wind direction most frequently observed during a given period. The periods most frequently used are the observational day, month, season and year.

SOLAR RADIATION - The total electromagnetic radiation emitted by the sun.

STABLE - Pertaining to the atmosphere or an atmospheric layer in the condition of static stability, that is, an atmosphere whose temperature lapse rate and moisture distribution is such as to suppress vertical exchange of air.

STAGNATION - With respect to air pollution, the persistence of a given volume of stable air over a region, permitting an abnormal buildup of pollutants from sources within the region.

STATIC STABILITY - (Also called hydrostatic stability, vertical stability, convective or convectional stability) The state of the atmosphere when it is stable relative to vertical displacements. Such an atmosphere tends to remain stratified, in that any air that is displaced vertically is subjected to a buoyant force that tends to restore it to its original level.

Static stability is determined primarily by the temperature lapse rate; an inversion layer is an extreme example of a statically stable layer.

SURFACE INVERSION - (Or ground inversion) A temperature inversion based at the earth's surface; that is, an increase of temperature with height beginning at the ground level.

This condition is due primarily to greater radiative loss of heat at and near the surface than at levels above. Thus, surface inversions are common over land prior to sunrise and in winter over high-latitude continental interiors.

TEMPERATURE INVERSION - A layer in which temperature increases with altitude. The principal characteristic of an inversion layer is its marked static stability, so that very little turbulent exchange can occur within it. Strong wind shears often occur across inversion layers, and abrupt changes in concentrations of atmospheric particulates and atmospheric water vapor may be encountered on ascending through the inversion.

When, in meteorological literature and discussion an "inversion" is mentioned, a temperature inversion is usually meant.

THEODOLITE - An optical instrument which consists of a sighting telescope mounted so that it is free to rotate around horizontal and vertical axes, and graduated scales so that the angles of rotation may be measured. The telescope is usually fitted with a right-angle prism so that the observer continues to look horizontally into the eyepiece, whatever the variation of the elevation angle. In meterology, the theodolite is used principally to observe the motion of a pilot balloon.

TOTAL LIFT - The upward force produced by the gas in a balloon. It is equal to the sum of the free lift, the weight of the balloon, and the weight of auxiliary equipment carried by the balloon.

WIND - Air in motion relative to the surface of the earth. Since vertical components of atmospheric motion are relatively small, especially near the surface of the earth, meteorologists use the term to denote almost exclusively the horizontal component. Vertical winds are always identified as such.

WIND ROSE - Any one of a class of diagrams designed to show the distribution of wind direction experienced at a given location over a considerable period; it thus shows the prevailing wind direction. The most common form consists of a circle from which eight or sixteen lines emanate, one for each compass point. The length of each line is proportional to the frequency of wind from that direction; and the frequency of calm conditions is entered in the center. Many variations exist. Some indicate the range of wind speeds from each direction; some relate wind directions with other weather occurrences.

WIND VANE - An instrument used to indicate wind direction.

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